High-Resolution Beach and Nearshore Monitoring Year 1:

Bogue Banks & Pine Knoll Shores—Indian Beach Phase 1 Nourishment

Submitted to:
Carteret County Beach Commission
Carteret County Shore Protection Office
Carteret County

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Executive Summary

This report provides results of four high-resolution 3-D surveys conducted at quarterly intervals on Bogue Banks between May, 2002 and April, 2003. Two of the surveys covered the entire island, and the other two focused only on the Phase I nourishment project at Pine Knoll Shores and Indian Beach. Each survey extended from the toe of the dune to a water depth of –33 ft (-10 m).

The primary goal of the surveys was to create a 3-D gridded surface that could be used for 1) determining an accurate Mean High Water (MHW) shoreline, 2) assessing changes in sediment volume between surveys, and 3) identifying morphologic trends that may provide insight into sediment dynamics and budgets. We have packaged the results of the surveys into interactive CDs that allow recipients of this report to have access to all of the 3-D data, as well as various shape and layer files for "zooming-in" on particular areas of interest.

The text that follows offers an assessment of the major findings, with particular emphasis on the Phase I nourishment section. It is clear that, even within the nourishment section, the island is complex, highly variable and that the nourishment project is still equilibrating. Results indicate that:

1) between a pre-nourishment survey in 2000 and our first post-nourishment survey in May, 2002 the MHW shoreline in the Phase I nourishment section moved seaward an average of nearly +100 ft (+30 m);

2) as the nourished beach equilibrated, the shoreline moved an average of –4.3 ft (-1.3 m) landward between May and August, 2002 and –33.8 ft (-10.3 m) landward between August and January, 2003;

3) by the end of the one-year period of monitoring (April, 2003), the MHW shoreline had moved back in a seaward direction by +9.8 ft (+3.0 m), resulting in a net one-year change of –27.9 ft (-8.5 m);

4) between the toe of the dune and a water depth of –20 ft (-6 m) along the nourishment section, the beach lost an average of –8.4 yd^3/ft (-21.1 m^3/m)

and the offshore region gained an average of +5.4 yd^3/ft (+13.5 m^3/m) over a one-year period;

5) most of the shift in sand volume occurred between August, 2002 and January, 2003, when the nourished beach lost an average of –9.3 yd^3/ft (-23.2 m^3/m); and,

6) the onshore and offshore movement of sand leaves un-reconciled volume discrepancies, indicating that significant sand exchange may be occurring in the longshore direction and in water depths greater than –20 ft (-6 m).

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1.0 Introduction

1.1 Scope and Purpose of Study

In May, 2002 the University of North Carolina-Chapel Hill, Institute of Marine Sciences, contracted with the Carteret County Board of Commissioners, through the Carteret County Beach Commission, to conduct a one-year study entitled *Pine Knoll Shores & Indian Beach High Resolution Beach and Nearshore Mapping Project.* [Subsequent to the award of this contract, the Board of Commissioners entered into a contract with the N.C. Division of Coastal Management to defray part of the project costs]. The study was designed to monitor morphology of the beach system along approximately 25 miles of Bogue Banks, placing special emphasis on the Phase I Pine Knoll Shores/Indian Beach nourishment project that was completed in April, 2002. The overarching goal of the project was to provide a basic framework and initial level of understanding of island behavior and nourishment performance that the county could use in designing future projects and in determining long-term costs for those projects. During the course of the study, it became clear that project data could also provide important background information for FEMA, the U.S. Army Corps of Engineers and the North Carolina Division of Coastal Management.

Specific objectives of the project were to: 1) collect high-density shore-normal and shore parallel survey data to create 3-D terrain models that maximize the potential for interpolation between profile stations, 2) use the gridded surfaces to extract a highly accurate shoreline position relative to mean high water (MHW) using a datum-derived (as opposed to a wet/dry line) position based on the 19-year tidal epoch, 3) assess beach and nearshore volume changes at previously-established profiling stations spaced, on average, 1000 ft apart, and 4) identify important morphological trends that will provide insight into sediment transport, as well as onshore, offshore and longshore sediment budgets. Results cover the period from May, 2002 to April, 2003 and include two island-wide surveys (May, 2002 and January, 2003) and two additional surveys (August, 2002 and April, 2003) of the Phase I nourishment area. In the following paragraphs, we discuss the highlights of our findings and present the results in summary form. The accompanying CDs include raw data, the GIS database, shape and layer files associated with the project, ArcExplorer for viewing data products, additional summary tables and profiles, and pertinent metadata for future reference. Following standard scientific practice, we have used SI (Standard International) units in all computations and in tabular and graphical presentations. However, at the request of the Beach Commission, we have used standard English units in the text and for presenting summary statistics on the graphs. A conversion table is included at the end of this report.

1.2 Background and Rationale

Beach nourishment has become standard practice and perhaps the best temporary solution for long-term erosion and storm protection management in North Carolina. The factors that affect beach nourishment performance, such as sediment grain size, offshore bathymetry and longshore transport processes, vary from location to location and it is clear that our ability to predict performance is modest at best. It is widely agreed that 1) better shoreline and offshore monitoring is needed statewide, particularly in areas where nourishment is being performed or is under consideration, and 2) monitoring data that are currently being collected should be made more readily available and in more useable formats. In order to better understand project performance and fate of nourishment material that is redistributed from the recreational beach, the direction and magnitude of sediment transport is needed on timescales of 1-10 years.

Historically, relatively accurate but time-consuming ground-based monitoring has been conducted as part of the design and maintenance phases of beach nourishment projects, but generally not for gaining a greater scientific understanding that could be applied to future projects. Measurements and sediment samples are typically collected from stable reference points established along the beach and may extend to a depth of about 30 ft, the hypothetical depth below which sediment exchange with the offshore region no longer takes place. Spacing of 2-D profiles lines is usually too large to allow meaningful interpolation between them and, as a result, geomorphic patterns, local erosional hotspots and changes in sediment characteristics may not be adequately described.

2-D elevation surveys often ignore the surf zone altogether. Yet, it is well known that the surfzone can retain considerable volumes of sediment that are periodically released to the beach in fair weather or stored in offshore sandbars during storms. In order to resolve geological features and redistribution patterns of nourishment material, 3-D data that spans the beach, surf zone and nearshore regions must be obtained accurately and frequently. This project was designed to do exactly that. The project took advantage of the fact that Phase I of a multi-phase nourishment project had been recently completed within a short distance of the Institute of Marine Sciences facilities, and that the technology and equipment were available for high-density, high-resolution data acquisition. At the request of the Beach Commission, we utilized the same profiling stations that were established for an earlier island-wide survey in 1999 and, insofar as was possible, utilized a monitoring design that could be copied in the future for later phases of nourishment.

2.0 Methods

Beach and nearshore morphology is spatially complex due to local variations in wave energy, engineered structures, offshore bathymetry, large-scale rhythmic topography, and tidal inlets. Many of the complex spatial changes, such as “hotspots” of erosion or accretion, may not be captured within a series of 2-D beach profiles, especially where the surfzone is ignored. To monitor nourishment performance and coastal processes along Bogue Banks, we required a more robust method of data acquisition and analysis that would accurately represent the true 3-D beach and nearshore morphology, as well as capture important 2-D profile data.

The acquisition method employed in this study utilizes advances in survey-grade or Geodetic Global Positioning Systems (GGPS) technology, coupled with Real-Time Kinematic baseline processing (RTK-GPS) and motion-compensated, shallow-water sonar. An important advantage over traditional beach surveying methods is the greater spatial coverage that can be achieved by running continuous data collection in parallel survey lines along the beachface and surfzone out to a depth of –33 ft (–10 m), tied together with cross-sectional lines collected from the dune base to the same water depth. Over a typical survey, this roughly equates to approximately 7000 data points every 1000 ft (305 m) out to –33 ft (-10 m). Data from the beach were collected using an ATV equipped with RTK-GPS, and the offshore data were collected using a rigid-hull inflatable boat, powered by jet drive and equipped with a survey-grade single-beam echosounder. A motion sensor corrected for heave, pitch and roll in boat motion. The beach and offshore lines overlapped in the surfzone (Figure 1). The integration of these technologies and this specific survey strategy has allowed us to combine repetitive, high-resolution beach and nearshore elevation data for the creation of seamless 3-D, grid-based maps for multi-user analyses in a GIS environment, as well as the collection of 2-D profile data with which to compare historical data.

Processing these data, representing shoreline topography and nearshore bathymetry with strong anisotropy (different orientations), provides a unique challenge. While density of points along individual beach and survey lines is very high (3-10 ft, 1-3 m apart), for practical reasons, the distance between the paths can be tens to hundreds of feet apart. To preserve most of the detail captured along-path and at the same time minimize the artifacts commonly created by trying to interpolate between the paths, we use what is referred to as “regularized spline with anisotropic tension and optimized parameters" to create 3-D surface representations of the study area. A detailed explanation of our calibration, acquisition and processing methods is outlined in Appendix A.

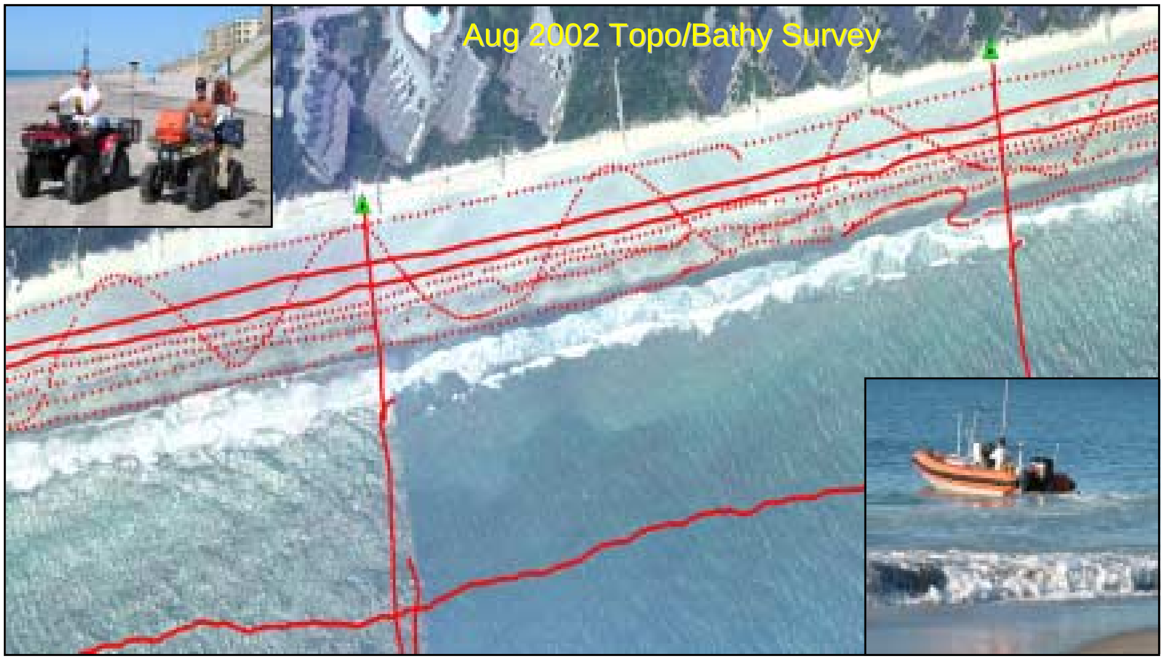


Figure 1. Vehicle assisted instrument platforms and the resulting data coverage.

3.0 Overview of Results

3.1 Changes in MHW Contour

Change in the datum-derived shoreline (or MHW contour) was analyzed within the Geographic Information Systems database through an extension developed by the US Army Corps of Engineers (USACE) called BeachTools (Hoeke, *et. al*, 2001). BeachTools allows us to automate the process of generating equally spaced and shore-normal transect lines across the entire stretch of Bogue Banks. In addition, the extension allows for the creation of baselines and ultimately facilitates precise measurements between the MHW contours. Figure 2 shows an example of a 1998 Digital Orthographic Quarter Quadrangle (DOQQ) with the MHW contours and generated transects for a segment of Emerald Isle.

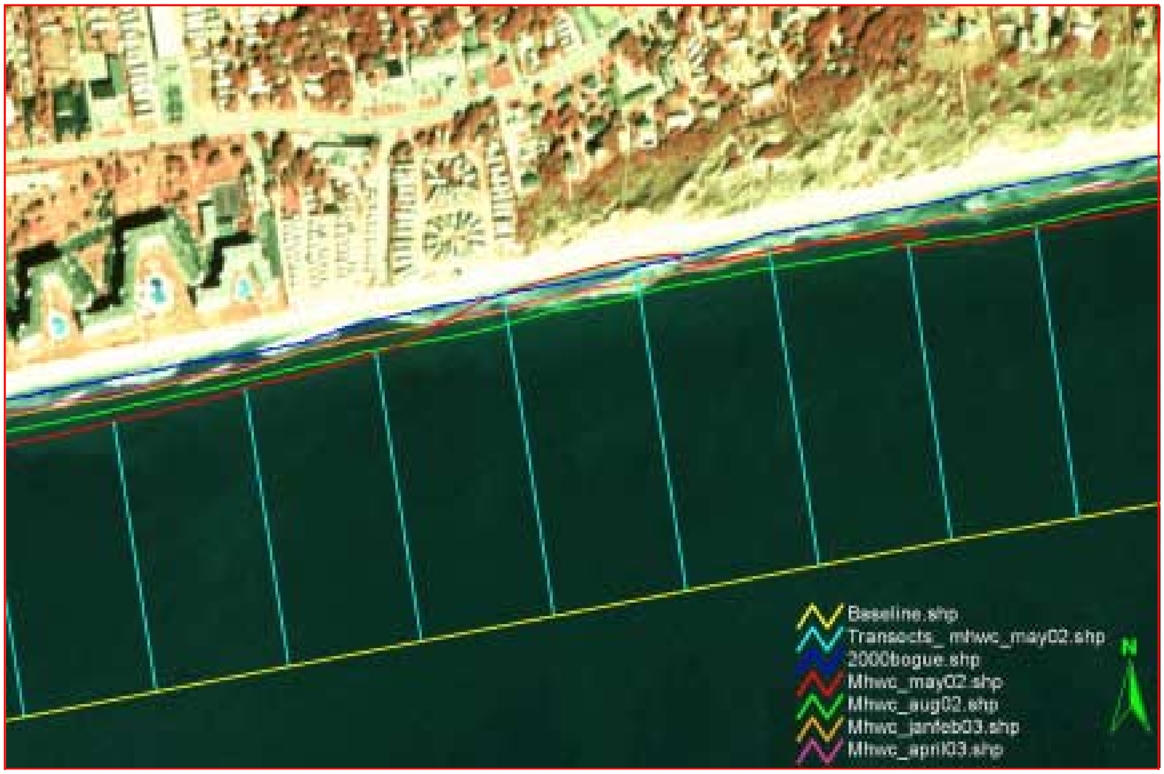
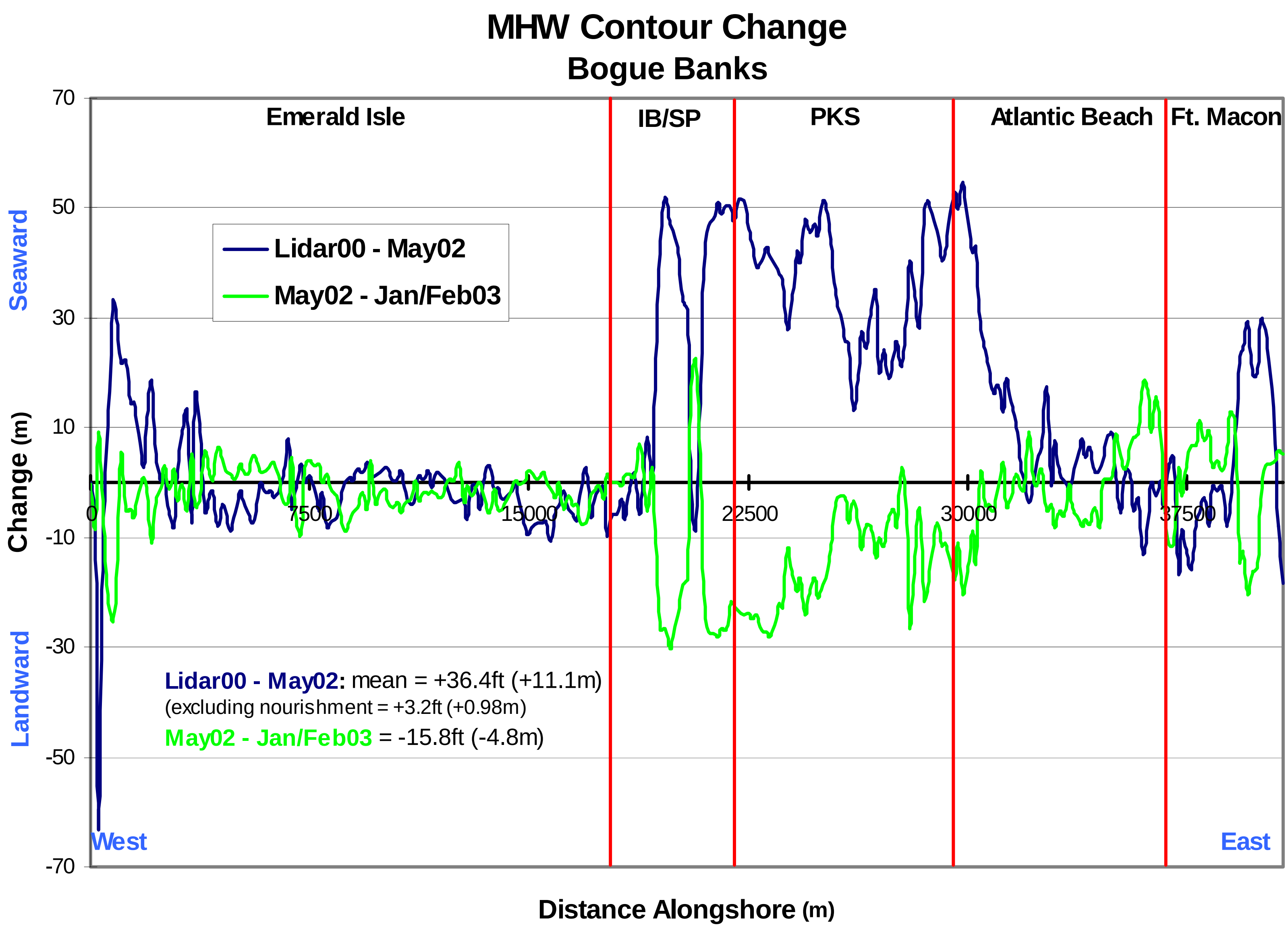


Figure 2. Baselines generated from the BeachTools ArcView extension overlaid on a 1998 DOQQ used to measure change between various MHW contours.

Results show that changes in the MHW shoreline were highly variable along the 25.2 mile (40,555 m) long surveyed section of Bogue Banks (Figure 3). In fact, temporal variability in the MHW contour along any given stretch of this beach is likely to be greater than the overall, island-wide shoreline changes. Comparison of a LIDAR (Light Identification, Detection and Ranging) 2000 pre-nourishment laser survey with the May, 2002 post-nourishment survey reveals several important features and trends, most notably 1) the prominent 9.1 mile long (14,640 m), Phase I nourished section of Pine Knoll Shores/Indian Beach, where the shoreline has built significantly seaward, 2) a section of modest shoreline change in eastern Emerald Isle, reflecting a relative degree of stability along this part of Bogue Banks, 3) a trend towards increasing shoreline change in western Emerald Isle near Bogue Inlet and on eastern Bogue Banks near Beaufort Inlet, and 4) a general seaward-to-landward change in shoreline position between western Atlantic Beach and the Ft. Macon "jetty."



MHW Contour Change
Bogue Banks
Emerald Isle
IB/SP
PKS
Atlantic Beach
Ft. Macon
Lidar00 - May02
May02 - Jan/Feb03
Seaward
Change (m)
Landward
70
50
30
10
-10
-30
-50
-70
0
7500
15000
22500
30000
37500
Lidar00 - May02: mean = +36.4ft (+11.1m)
(excluding nourishment = +3.2ft (+0.98m)
May02 - Jan/Feb03 = -15.8ft (-4.8m)
West
East
Distance Alongshore (m)

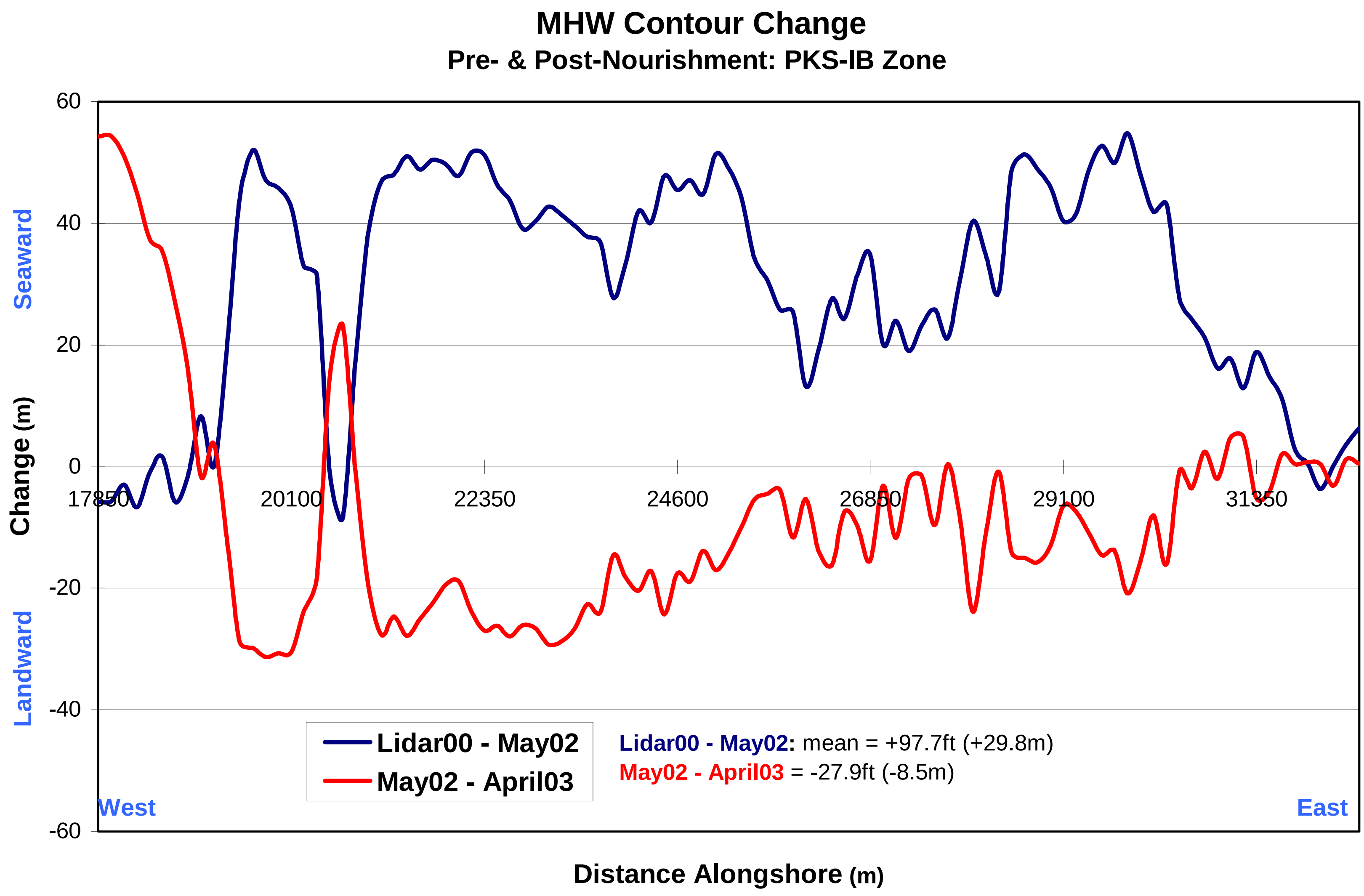
Figure 3

Average shoreline change between the pre- and post-nourishment surveys was +36.4 ft (+11.1 m) over the entire island, and +3.2 ft (+0.98 m) for sections of the island outside of the Phase I nourishment area (Figure 3). Although these (positive) values indicate that Bogue Banks has undergone progradation rather than erosion, even outside the nourishment area, this interpretation requires clarification. In addition to the new sediment added from Phase I nourishment, there were also contributions from 1) disposal of approximately 210,000 yd^3 of dredged sediment at Ft. Macon in the several months prior to our May, 2002 survey, and 2) significant recent buildup of sediment on beaches of western Emerald Isle from changes in the ebb tidal delta of Bogue Inlet. Moreover, as noted in the CSE Survey Report (2000) on Bogue Banks that included the effects of Hurricane Floyd, sediment that is eroded from the foredunes can result in localized and temporary seaward movement of the shoreline.

Indeed the state's most recent shoreline erosion update (from 1998 aerial surveys) indicates that average erosion rates on Bogue Banks are 2-3 ft/yr (0.6-0.9 m) with localized hotspots along sections of Pine Knoll Shores and Indian Beach, where rates exceed 5 ft/yr (1.5 m). Results from our two island-wide surveys (May, 2002 and January, 2003) showed a net landward change of -15.8 ft (-4.8 m) in MHW over this short period of time (Figure 3). Much of this change can be attributed to equilibration of the nourishment sediment at Pine Knoll Shores/Indian Beach, and to the fact that the period of observations captures the natural summer-to-winter changes in beach profile. Figure 3 also shows what appears to be an important island-wide pattern of shoreline change: areas both within and outside the nourishment project that prograded (moved seaward) between the LIDAR 2000 and May, 2002 surveys tended to move landward between May, 2002 and January, 2003, and vice versa. This pattern is revealed by the general mirror-like patterns of the two sets of survey data.

Figure 4 shows in greater detail the changes within the Phase I nourishment section of the island. Using the LIDAR 2000 survey as a base, there was considerable variability in the amount of seaward shoreline movement, reflecting in part the variable nature of the MHW shoreline prior to nourishment. The MHW contour built seaward an average of +97.7 ft (+29.8 m) and revealed a tapered pattern at the east and west margins. Over the one-year observation period, May, 2002 – April, 2003, the MHW contour moved landward an average of -27.9 ft (-8.5 m), and revealed localized MHW contour adjustments that ranged from –103.3 ft (–31.5 m) to +77.1 ft (+23.5 m). As a generalization, areas that moved farthest seaward from the addition of nourishment sediment, also showed the largest amount of landward adjustment (mirror effect) from subsequent equilibration of the profile. A large hole, which was left near the western end of the section (12.8 miles; 20,600 m) due to an abrupt early termination of the project, provided an excellent reference site for assessing sediment transport and infilling processes (see Section 3.2).

Figure 5 shows the quarterly sequence of the equilibration process. Initial adjustment between May, 2002 and August, 2002 was highly variable with an average landward movement of –4.3 ft (-1.3 m). During this 3-month period of profile adjustment, the nourishment hole filled rapidly, apparently from both sides. The west end of the project, in the area where the nourishment profile tapered into the existing island profile, also showed rapid seaward movement of the MHW contour. We conclude that this progradation of the beach occurred because nourishment material was being spread to the west by processes of longshore sediment transport. Contour changes between August, 2002 and January, 2003 averaged –33.8 ft (-10.3 m), reflecting the onset of the winter season and loss of sediments to offshore areas. However, by April, 2003, following the last quarterly survey, there was less variability in change and an overall shift of the shoreline by +9.8 ft (+3.0 m) in a seaward direction. Although April would be considered quite early for reestablishment of the summer profile, this in fact appears to be what happened. It is clear from the contour data alone



MHW Contour Change
Pre- & Post-Nourishment: PKS-IB Zone
60
40
20
0
-20
-40
-60
Seaward
Change (m)
Landward
17850
20100
22350
24600
26850
29100
31350
Lidar00 - May02
May02 - April03
Lidar00 - May02: mean = +97.7ft (+29.8m)
May02 - April03 = -27.9ft (-8.5m)
West
East
Distance Alongshore (m)

Figure 4

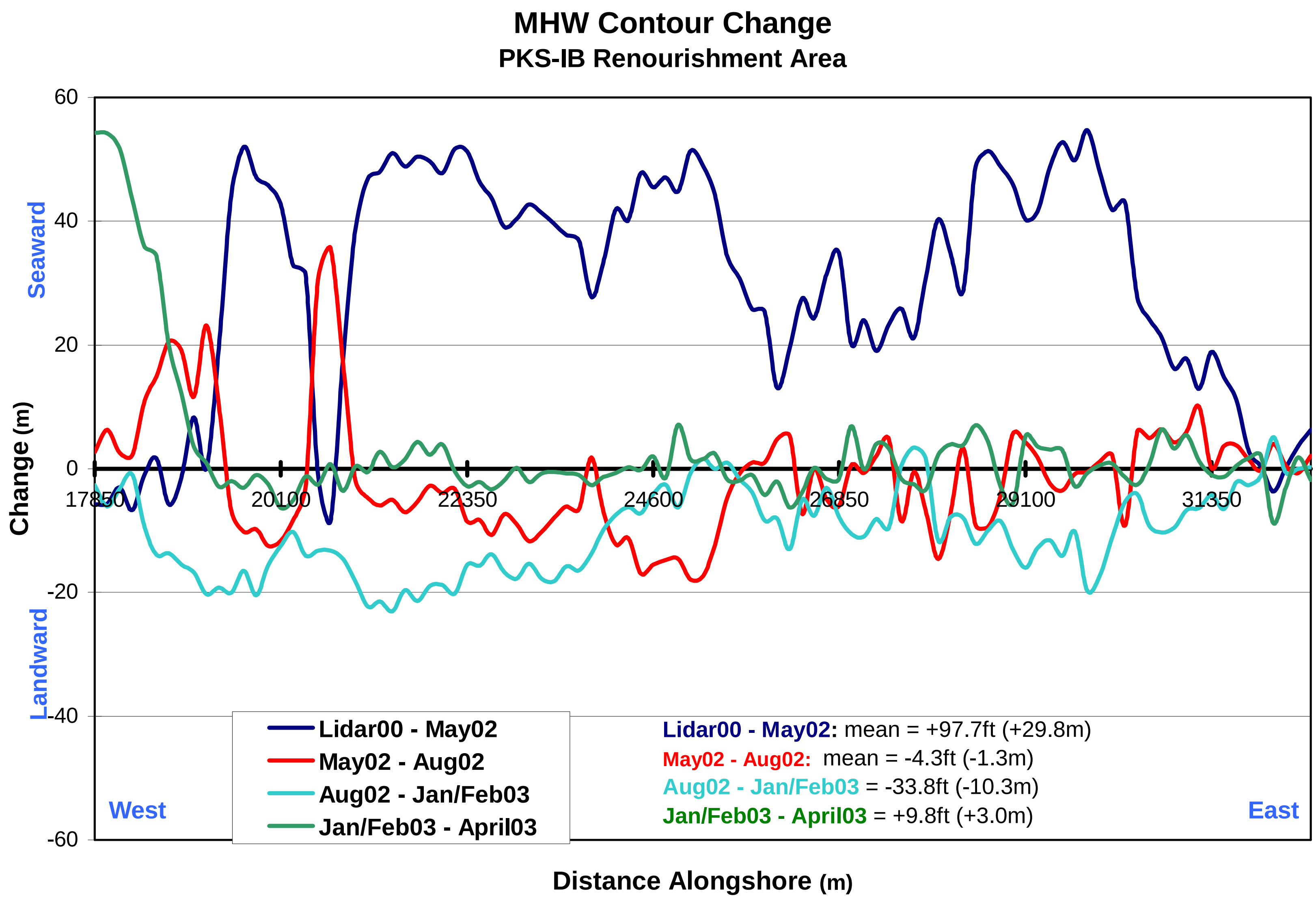

MHW Contour Change
PKS-IB Renourishment Area
60
40
20
0
-20
-40
-60
Seaward
Landward
Change (m)
17850
20100
22350
24600
26850
29100
31350
Distance Alongshore (m)
West
East
Lidar00 - May02
May02 - Aug02
Aug02 - Jan/Feb03
Jan/Feb03 - April03
Lidar00 - May02: mean = +97.7ft (+29.8m)
May02 - Aug02: mean = -4.3ft (-1.3m)
Aug02 - Jan/Feb03 = -33.8ft (-10.3m)
Jan/Feb03 - April03 = +9.8ft (+3.0m)

Figure 5

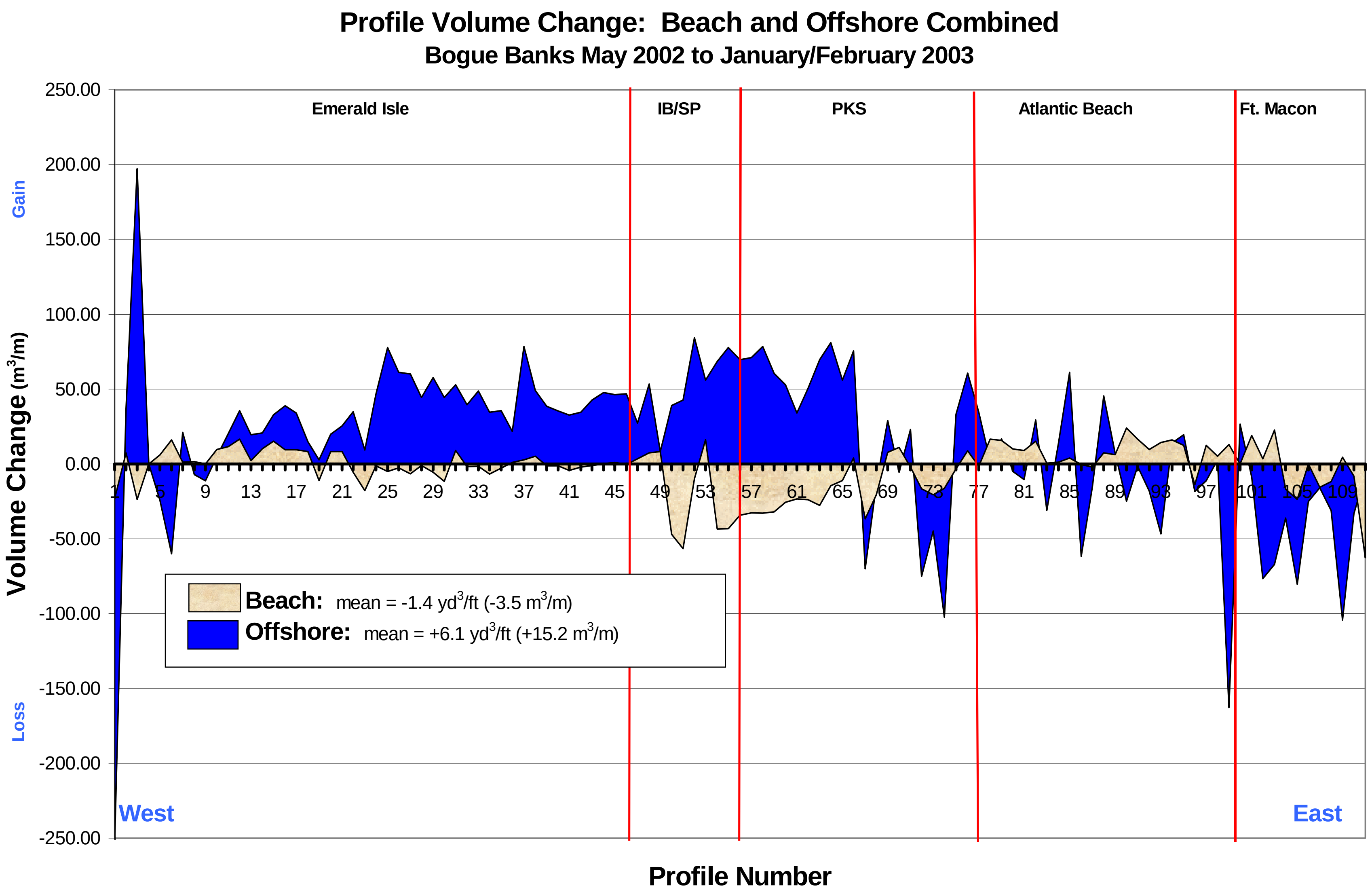
that the large losses of nourishment material during the first three quarters of the observation period remained close enough to shore to be easily returned. Observations confirmed that this cover of returned material was largely devoid of coarse shell.

3.2 Changes in Profile Volume

The change in sand volume is a fundamental indicator of island stability and an important measure used in determining directions and rates of sediment transport. Figure 6 shows the changes in volume that were computed from the two island-wide surveys (May, 2002 and January, 2003) at each of the 111 profile stations (Appendix B). Each profile station had a common base or starting point (tied to location and condition of the dune) that was used in the successive surveys at that station. For convenience, data were divided into an onshore or beach compartment, between the common base down to Mean Lower Low Water (MLLW), and an offshore compartment, between MLLW and -20 ft (- 6 m). [Note: we truncated the offshore volume calculations at –20 ft (-6 m) because of increasing uncertainty in acoustic soundings beyond that depth. Many of the station profiles showed increasing sediment volumes farther offshore and these may in fact be real]. As with the MHW shoreline, considerable variability in volume could be observed along the island, and in many cases between closely spaced profile stations. Profiles showed that there were sections of the island that gained sand in both beach and offshore areas (western Emerald Isle, stations 11-20), lost sand in both beach and offshore areas (Ft. Macon, profile stations 106-111), and sections where the beach and offshore areas displayed opposite gain-loss trends (Phase I nourishment, profile stations 52-68).

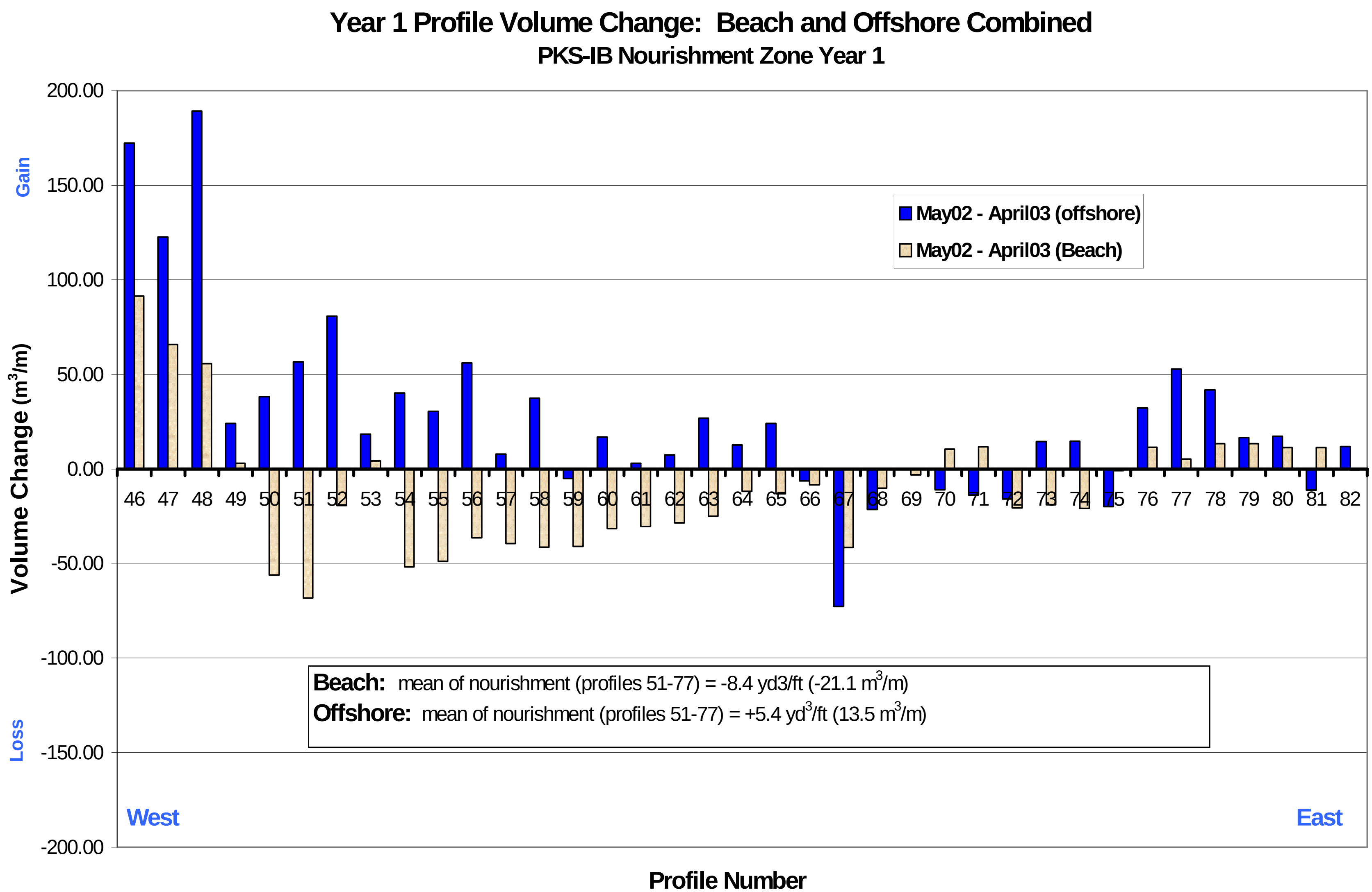
The overall change in volume equated to a net loss on the beach of -1.4 yd^3/ft (-3.5 m^3/m) and a net gain offshore of +6.1 yd^3/ft (+15.2 m^3/m). Across the entire survey area, Bogue Banks gained +4.7 yd^3/ft (+11.7 m^3/m) or a total of 625,360 yd^3 (478,150 m^3) of sand. Most of the gain in sand was concentrated on the western half of the island, particularly in the Phase I nourishment area and throughout most of Emerald Isle (Figure 6). Except for a section along Ft. Macon, where the beach and offshore areas both lost sand, and throughout the Phase I nourishment area where sand from the beach was lost, most of the other losses were rather isolated and restricted to only a few profile stations. The positive sand balance across the entire survey area, although a relatively small value (representing less than 10% of the volume of sand added to the Phase I nourishment area per ft of beach), was nevertheless unexpected. Much of the sand may have come from dune erosion in Emerald Isle, landward of our common base for the profile stations, thereby building up the measured volume of sand between the two survey periods from “outside” sources of material. In the eastern section of Emerald Isle (profile stations ~25-49), where the beach showed little change in volume over time, it appears that sand was carried from the dunes directly offshore; in the western section (profile stations ~11-23), where the beach gained sediment volume as well, some of the sediment derived from the dunes was retained above the MLLW line and the remainder moved offshore. Further details on specific areas of interest can be obtained from the enclosed CD.

Figure 7 shows detailed results of volume changes over the one-year period of observations in the Phase I nourishment area. Here, the trend was loss of sediment from the beach and gain in sediment offshore. The beach lost an average of -8.4 yd^3/ft (-21.1 m^3/m) between stations 51 and 77, whereas the offshore area gained an average of +5.4 yd^3/ft (+13.5 m^3/m) out to the -20 ft (-6 m) depth. Failure to account for all of the beach sediment in the offshore region at the approximate one-year anniversary of the nourishment project can be attributed to transport of beach sand in the longshore direction (as opposed to offshore transport), or to transport of sand beyond the -20 ft (-6 m) water depth, where it would no longer appear in our budget calculations. The large positive volume change in beach and offshore sand immediately west of station 50 is a result primarily of Phase II nourishment, which added approximately +82 yd^3/ft



Profile Volume Change: Beach and Offshore Combined
Bogue Banks May 2002 to January/February 2003
Emerald Isle
IB/SP
PKS
Atlantic Beach
Ft. Macon
Gain
Loss
Volume Change (m³/m)
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
1
5
9
13
17
21
25
29
33
37
41
45
49
53
57
61
65
69
73
77
81
85
89
93
97
101
105
109
Beach: mean = -1.4 yd³/ft (-3.5 m³/m)
Offshore: mean = +6.1 yd³/ft (+15.2 m³/m)
West
East
Profile Number

Figure 6



Year 1 Profile Volume Change: Beach and Offshore Combined
PKS-IB Nourishment Zone Year 1
Gain
Loss
Volume Change (m3/m)
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
May02 - April03 (offshore)
May02 - April03 (Beach)
46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82
Beach: mean of nourishment (profiles 51-77) = -8.4 yd3/ft (-21.1 m3/m)
Offshore: mean of nourishment (profiles 51-77) = +5.4 yd3/ft (13.5 m3/m)
West
East
Profile Number

Figure 7

(+206 m^3/m) to the beach system. Stations 46-48, immediately west of the nourishment area, averaged a gain of +92 yd^3/ft (+231 m^3/m) of sediment (beach + offshore) indicating that sediment was probably moving alongshore to the west into this un-nourished reach. Similarly, localized transport to the east into Atlantic Beach (~profile stations 78-82) resulted in a modest net volume increase on the beach and offshore.

Two other features are noteworthy in Figure 7. Both were recognized because their morphologic behavior differed from adjacent areas. The first feature was the nourishment hole located in Salter Path and Indian Beach, which appeared prominently in the MHW contour data (Figure 4 & 8). Detailed analysis of shoreline change, measured from the center of the nourishment hole, indicated that over the 1-yr study, the shoreline accreted (moved seaward) by a maximum of +76.1 ft (+23.2 m) while the surrounding areas eroded approximately 80-100 ft (~25-30 m) over the same period (Figure 8).

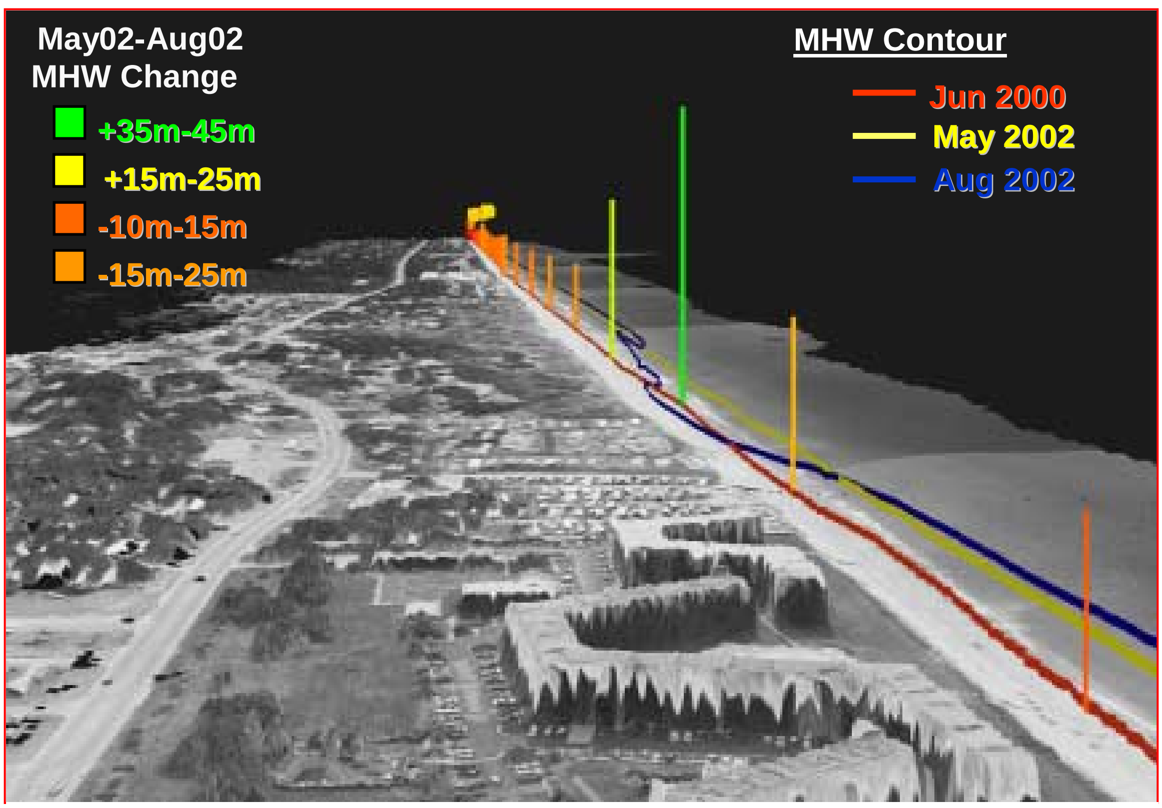


Figure 8. Oblique 3-D orthophoto with overlaid MHW contour and shoreline change data.

Sediment analysis revealed the presence of dark shell that was characteristic of the nourishment material. Moreover, this hole (near profile station 53) marked the only place within the entire Phase I nourishment reach (between profile stations 51-77) where sediment volume had increased on the beach *and* offshore after one year. Approximately +10 yd^3/ft (+25 m^3/m) of sand (combined beach and offshore) was added to this un-nourished section of the coast from natural processes of sediment transport**.** In order to quantify the shoreline change variability in terms of morphology, we calculated the grid volume and slope change from 3-D elevation models along a 1.5 mi (2.4 km) around the nourishment hole (Figure 9). From May to August there was approximately 104,000 yd^3 (80,000 m^3) of accretion and approximately 85,000 yd^3 (65,000 m^3) of erosion. Slope analysis illustrates that higher slopes (approx. 3^o to 5^o) were concentrated along nourished sections in May, and that the hole and the zone west of the nourishment boundary had much lower slopes (approx. 1^o to 3^o).

The second feature (between stations 66-68), an erosional “hotspot”, marked the only place within the Phase I nourishment project where sediment volume had decreased on the beach *and* offshore after one year. At its central location (profile station 67), approximately –46 yd^3/ft (-116 m^3/m) of sand (beach + offshore) were lost from this section of the nourishment profile over the course of a year. This section of Bogue Banks appears to be an erosional “hotspot” in the state’s long-term erosion rate figures and may be connected to underlying geologic features such as outcropping hard bottom deposits. Bathymetry data from profile 65 provides evidence for outcropping geology between –13 ft (-4 m) and –33 ft (-10 m) with a distinct trough and “table top” type features not measured in any of the other profiles. It is also interesting, and possibly significant, that this region of chronic erosion and profiles 64-67 are geographically related to the termination of the recurved beach ridges that characterize this part of the island’s topographic landscape (Figure 10).

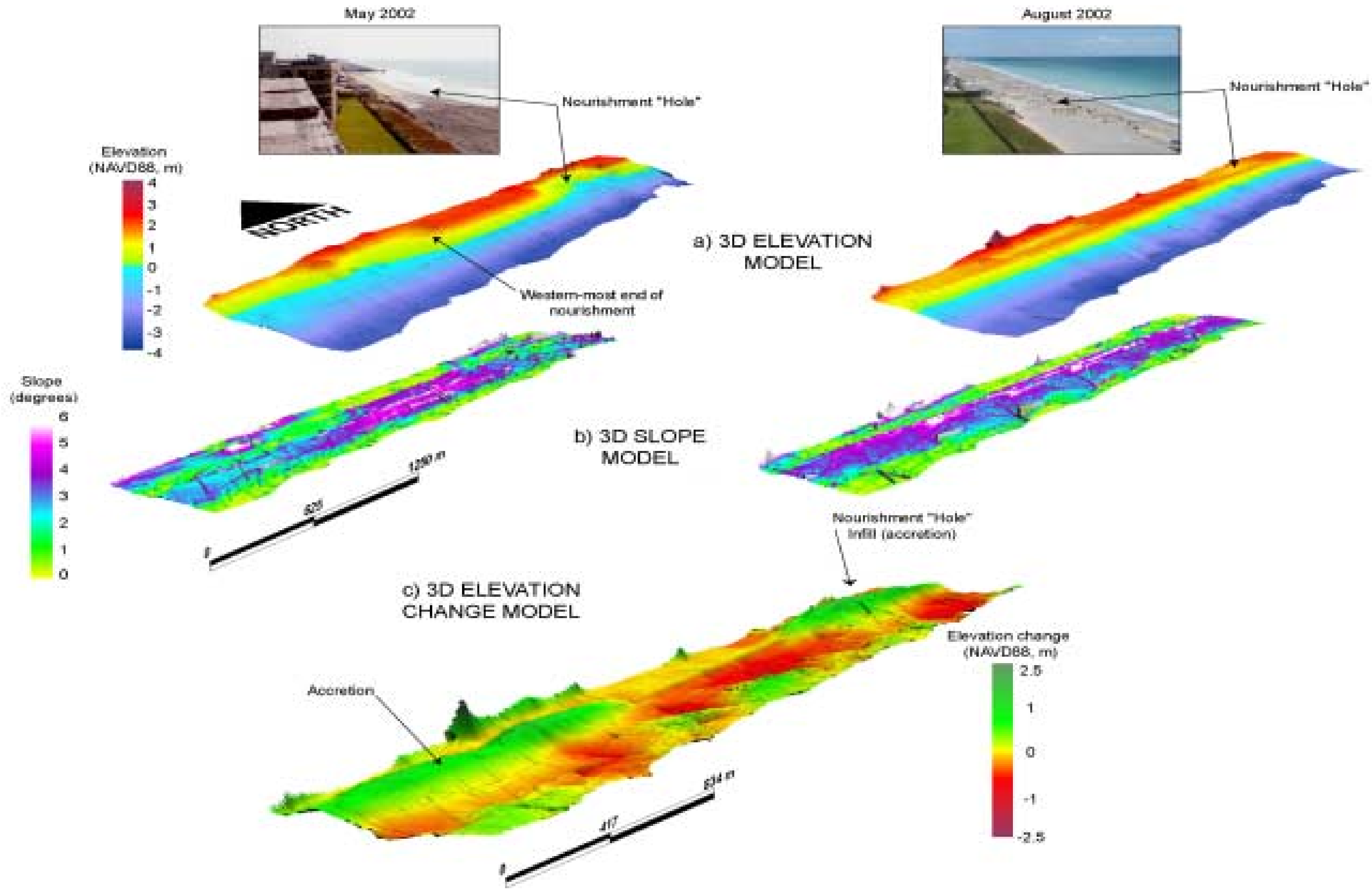


Figure 9. 3D topographic models of the nourishment hole area. a). elevation model. b). slope model. c). elevation change model.

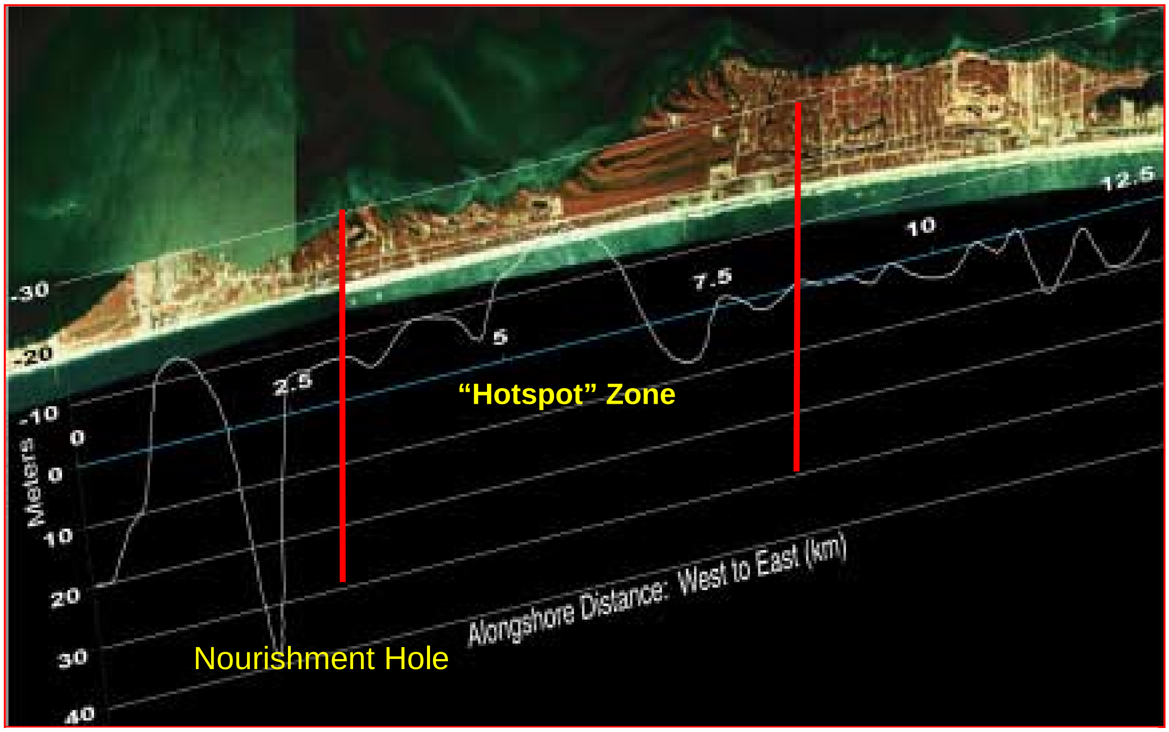
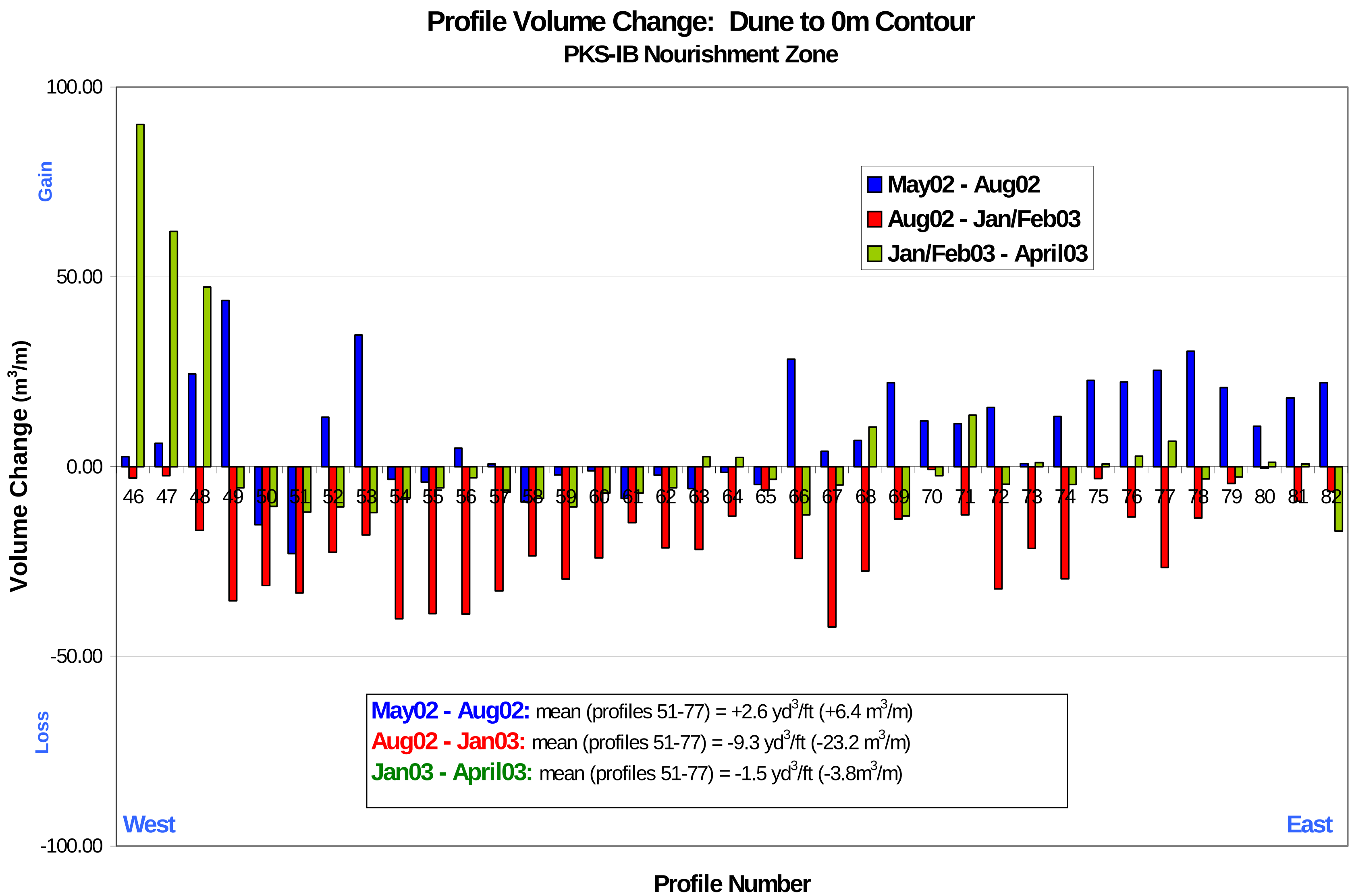


Figure 10. May 2002 to August 2002 georeferenced shoreline change data overlaid on a 1998 DOQQ showing "hotspot" zone in relation to the islands geomorphology.

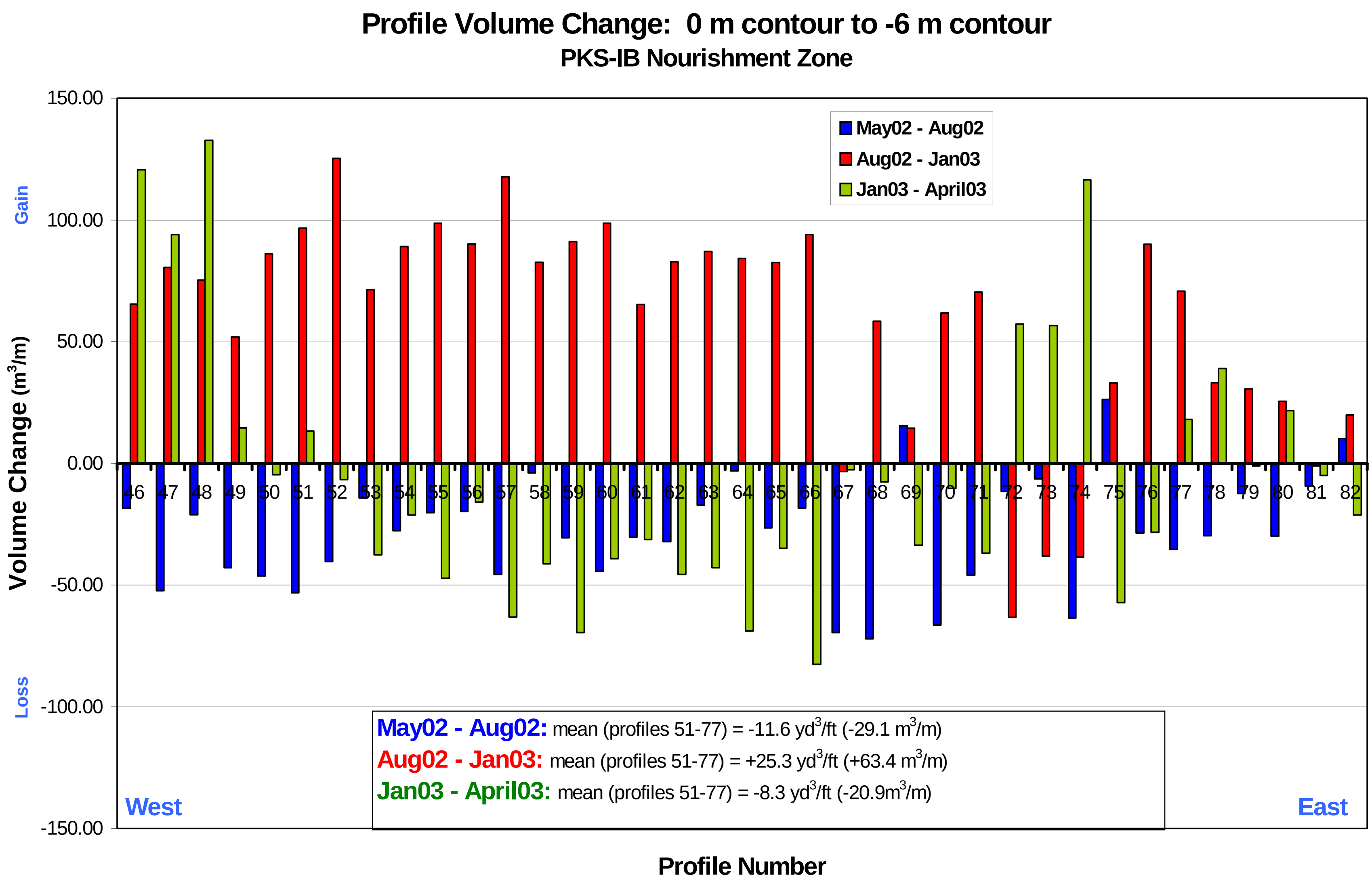
Figure 11 shows the quarterly sequence of volume changes in the nourishment area along the beach (common base to MLLW) part of the profiles. During this first period of profile adjustment, May, 2002-August, 2002, the eastern half of the project gained sediment and the western half, except in the vicinity of the nourishment hole, lost sediment. The net change, +2.6 yd^3/ft (+6.4 m^3/m), was very small but probably real. This additional sediment may have been derived from the east, outside the nourishment area, or from offshore as would be expected during the summer. Nearly every profile station displayed a loss in offshore sediments during this period (Figure 12), averaging -11.6 yd^3/ft (-29.1 m^3/m). The fact that the western half of the nourishment area did not gain sediments on the beach can be attributed to longshore transport to the west. Most of the volume loss on the beach (-9.3 yd^3/ft; -23.2 m^3/m) occurred between August, 2002 and January, 2003. This was a period during which gains in offshore volume (+25.3 yd^3/ft; +63.4 m^3/m) exceeded the above noted losses from the beach. We are unable to offer a full explanation for this discrepancy, but cautiously attribute most of the difference to profile adjustment below the –20 ft (-

6 m) contour offshore. The final period of observation, January, 2003-April, 2003, revealed very small additional volume losses on the beach (-1.5 yd^3/ft; -3.8 m^3/m) and larger volumes throughout most of the offshore region (-8.3 yd^3/ft; -20.9 m^3/m). The accompanying volumes of change for each of the 111 profile stations are given in Appendix B.



Profile Volume Change: Dune to 0m Contour
PKS-IB Nourishment Zone
Volume Change (m³/m)
Gain
Loss
100.00
50.00
0.00
-50.00
-100.00
46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82
May02 - Aug02
Aug02 - Jan/Feb03
Jan/Feb03 - April03
May02 - Aug02: mean (profiles 51-77) = +2.6 yd³/ft (+6.4 m³/m)
Aug02 - Jan03: mean (profiles 51-77) = -9.3 yd³/ft (-23.2 m³/m)
Jan03 - April03: mean (profiles 51-77) = -1.5 yd³/ft (-3.8m³/m)
West
East
Profile Number

Figure 11



Profile Volume Change: 0 m contour to -6 m contour
PKS-IB Nourishment Zone
May02 - Aug02
Aug02 - Jan03
Jan03 - April03
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
Gain
Loss
Volume Change (m3/m)
46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82
May02 - Aug02: mean (profiles 51-77) = -11.6 yd3/ft (-29.1 m3/m)
Aug02 - Jan03: mean (profiles 51-77) = +25.3 yd3/ft (+63.4 m3/m)
Jan03 - April03: mean (profiles 51-77) = -8.3 yd3/ft (-20.9m3/m)
West
East
Profile Number

Figure 12

3.3 Gridded 3-D Surfaces

The above profile stations represent 2-D slices through the beach and offshore regions along 111 transect lines that were previously established. Following standard practice, these 2-D lines have been converted to 3-D volumes by multiplying by a unit width (1 ft or 1 m) and extrapolating the profile volumes to “fill in” the 1000 ft space between adjacent lines. We have attempted to gain additional insight into volumetric changes by constructing a beach and offshore cell-based network along the entire island. The cell bounds were constructed using a landward datum common to all analyses obtained by “heads-up” digitizing of the dune base from the USACE 2002 DOQQs, the extraction of the MLLW contour (0 ft elevation) and the –19.7 ft (–6 m) contour from our interpolated surfaces generated from the collection of shore-perpendicular and shore-parallel survey data. The cells break the island into 14 compartments (G1-G14), each ~9800 ft (~3000 m) in length (Figure 13). Volumes are calculated from our interpolated grids (see Appendix A for interpolation algorithm information) within cells using the Spatial and 3D Analyst extensions in ArcView 3.3, and a smoothed plot of volume change is constructed.

The results of this analysis are shown in Figures 14-17. There is remarkable similarity between these figures and the equivalent bar graphs that are plotted, respectively, in Figures 6, 7, 11, and 12. The broad zones of volume change (equated to sediment erosion and sediment deposition) are depicted in a fashion that removes the high-frequency “noisiness” of the profile data while at the same time providing a more accurate interpolation *along* the island. The accompanying change volumes for each of the 14 reaches are given in Appendix C.

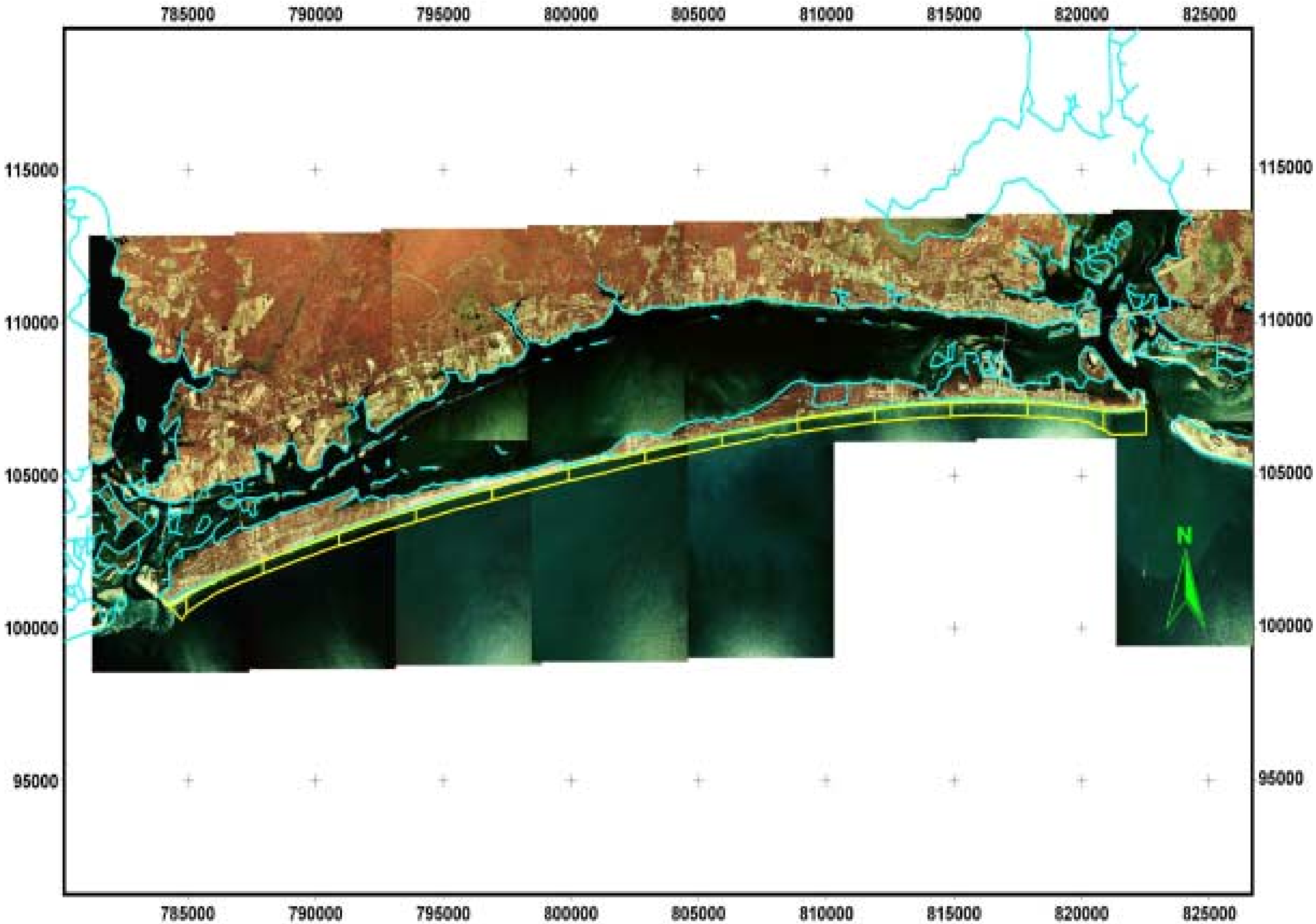


Figure 13. Location of grid cells used for calculating 3D grid volumes.

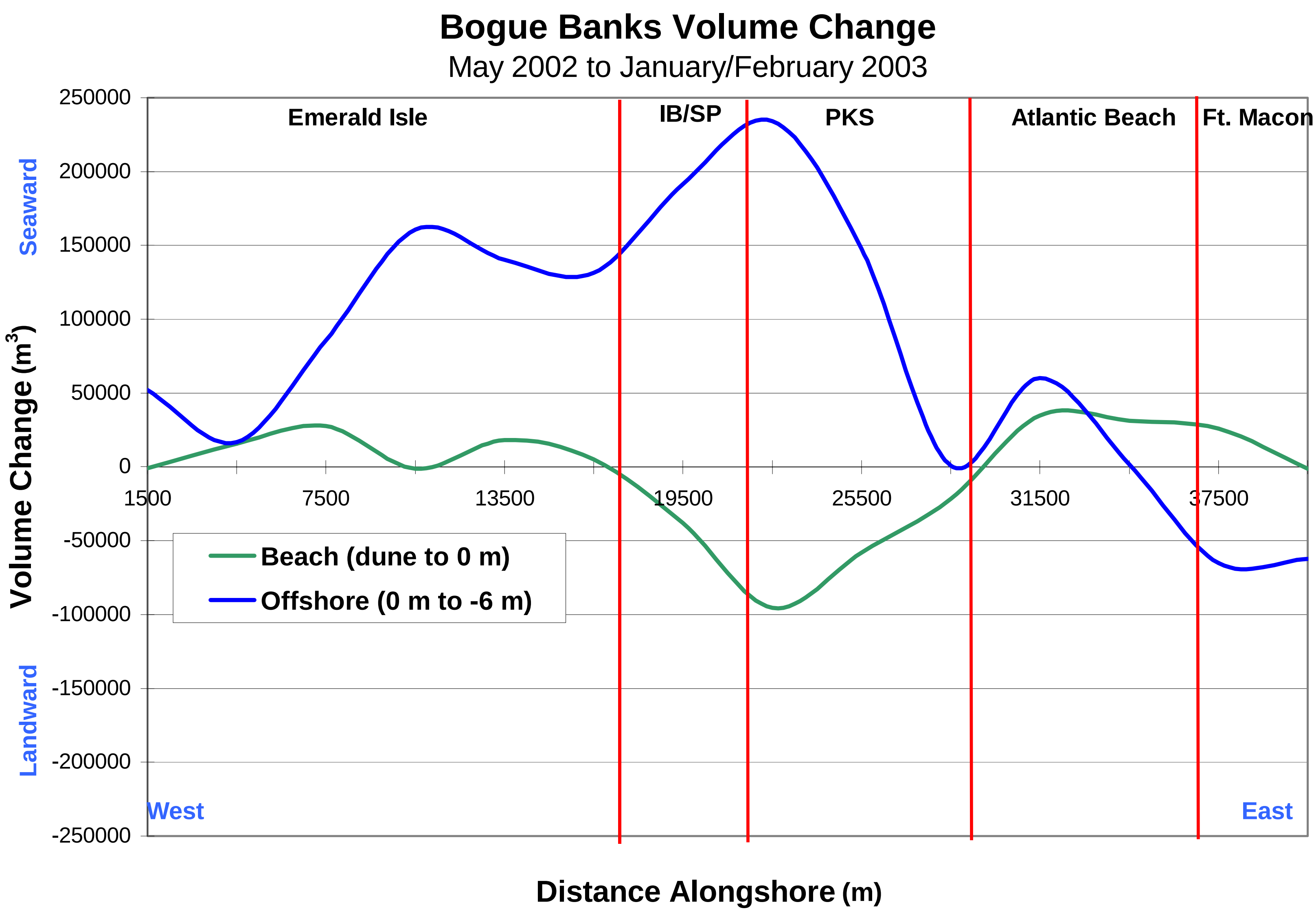
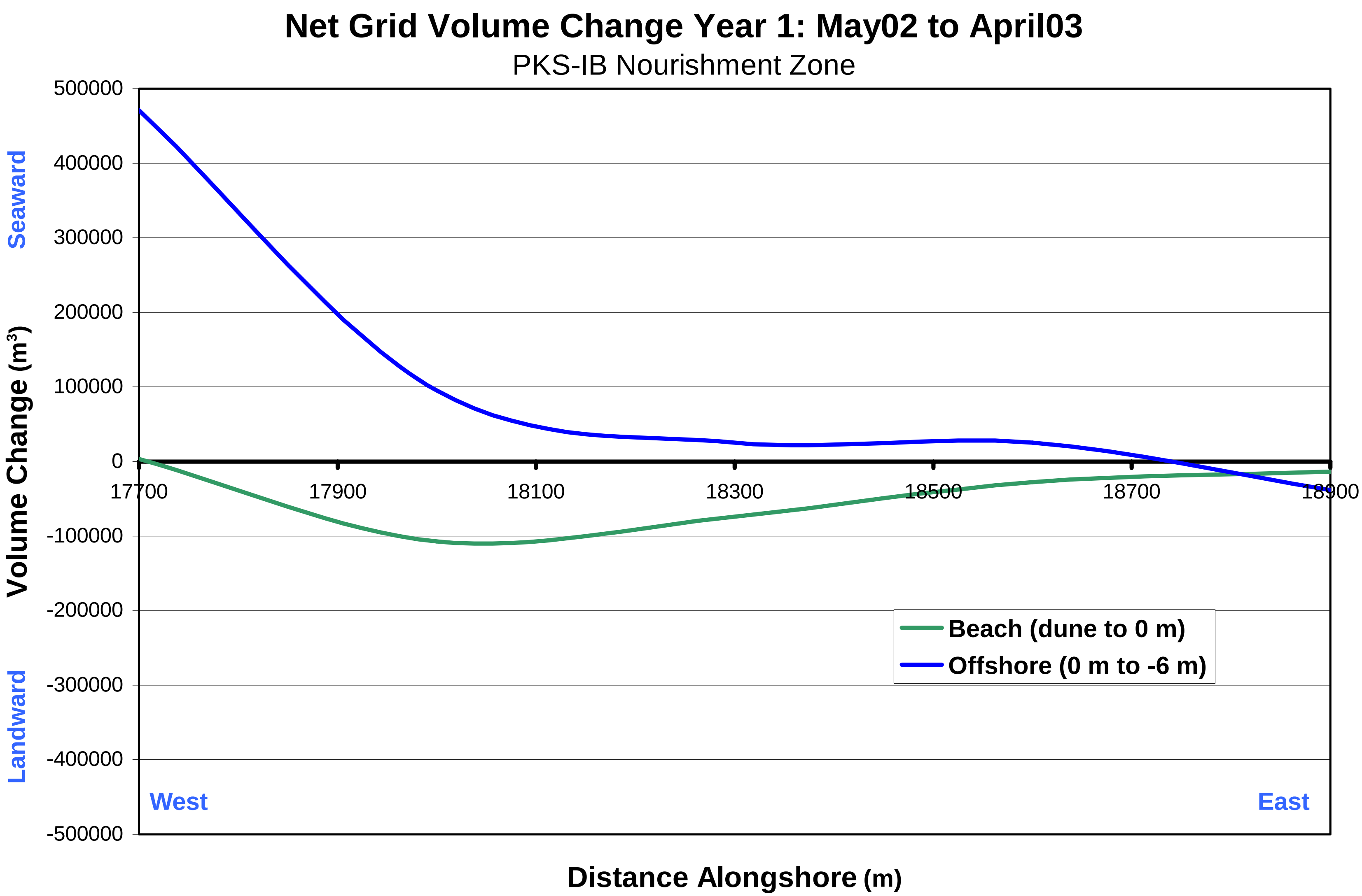

Bogue Banks Volume Change
May 2002 to January/February 2003
Emerald Isle
IB/SP
PKS
Atlantic Beach
Ft. Macon
Seaward
Landward
Volume Change (m3)
250000
200000
150000
100000
50000
0
-50000
-100000
-150000
-200000
-250000
1500
7500
13500
19500
25500
31500
37500
Beach (dune to 0 m)
Offshore (0 m to -6 m)
West
East
Distance Alongshore (m)

Figure 14



Net Grid Volume Change Year 1: May02 to April03
PKS-IB Nourishment Zone
Volume Change (m³)
Seaward
Landward
500000
400000
300000
200000
100000
0
-100000
-200000
-300000
-400000
-500000
17700
17900
18100
18300
18500
18700
18900
West
East
Beach (dune to 0 m)
Offshore (0 m to -6 m)
Distance Alongshore (m)

Figure 15

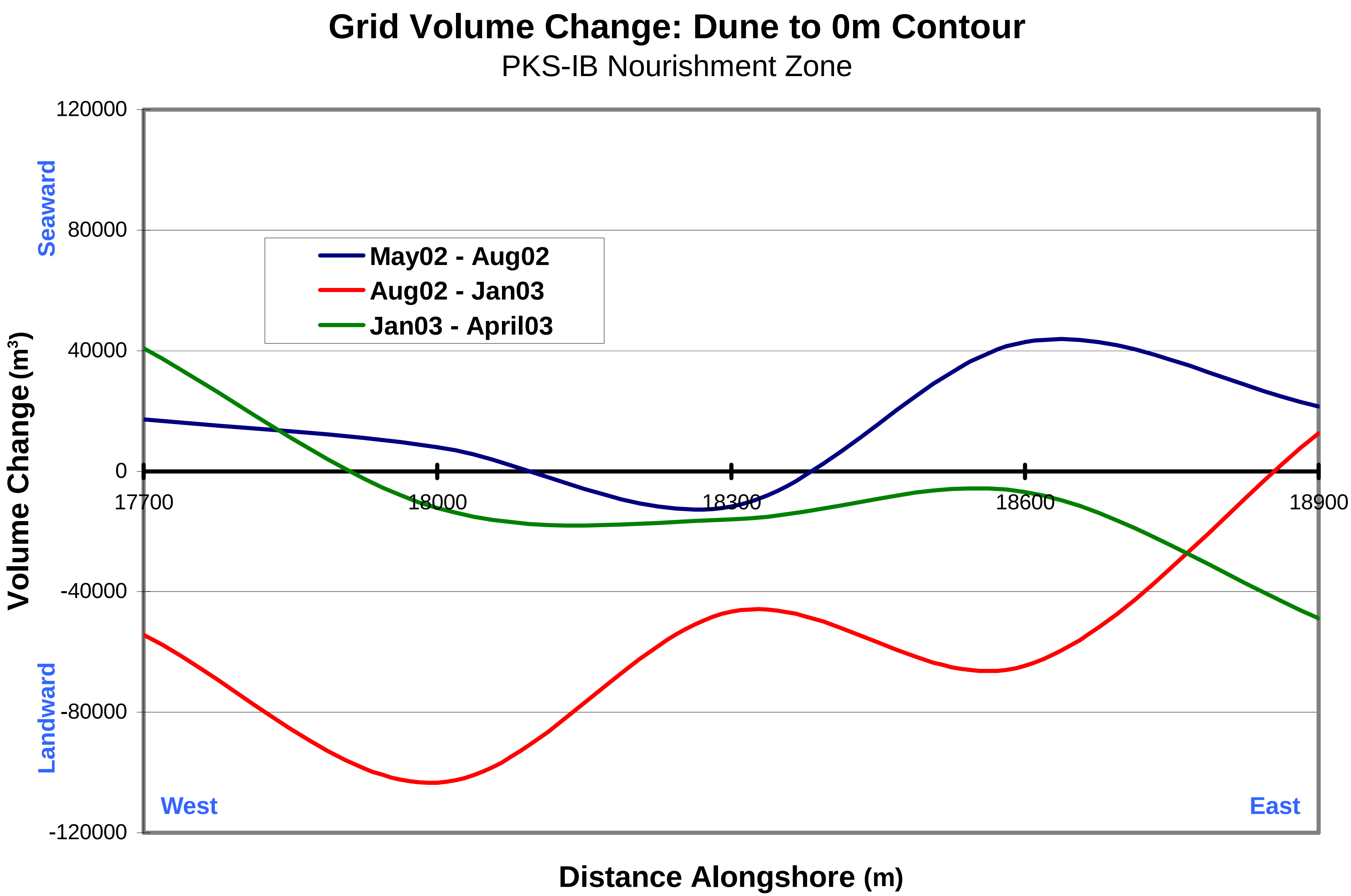
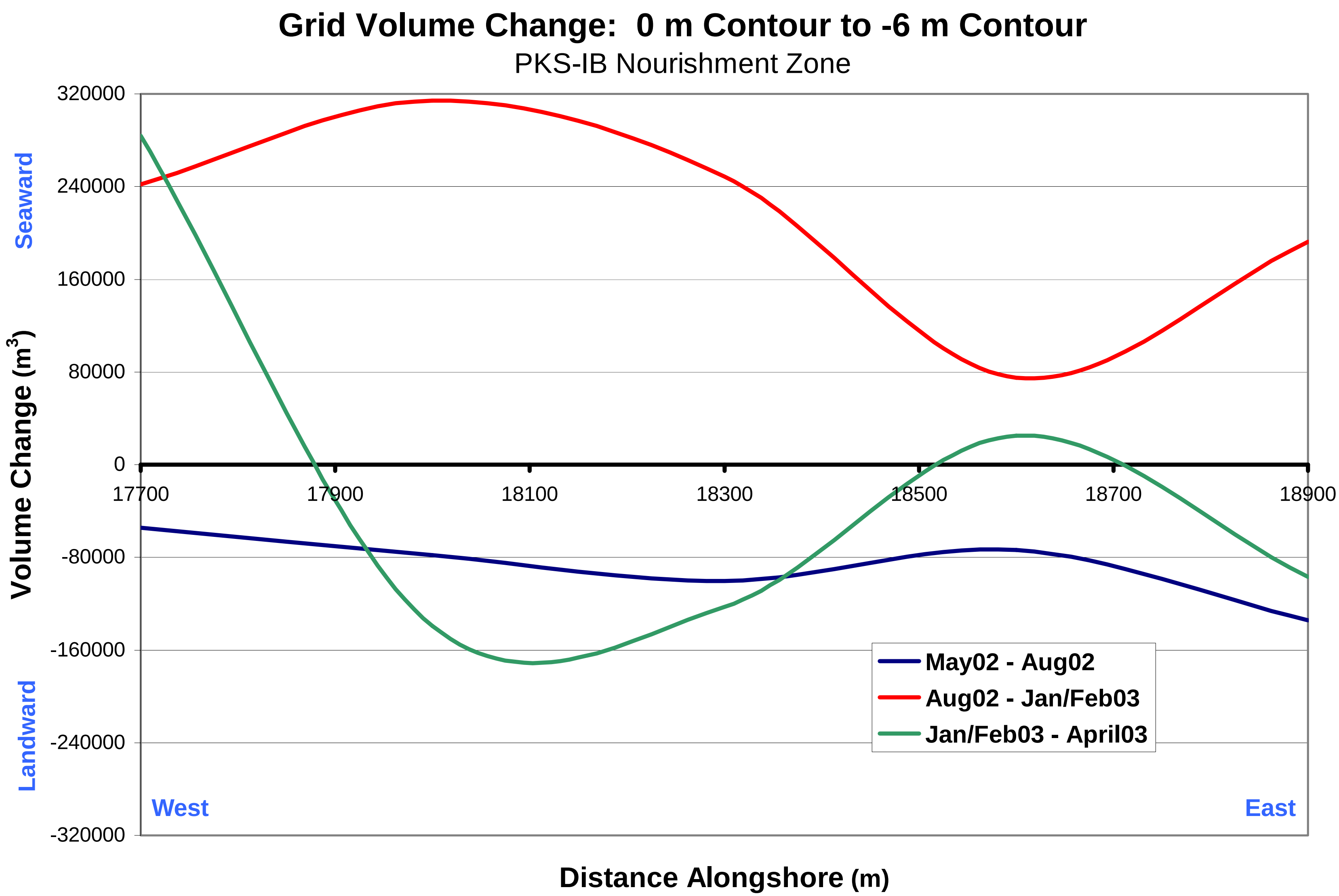

Grid Volume Change: Dune to 0m Contour
PKS-IB Nourishment Zone
120000
80000
40000
0
-40000
-80000
-120000
Seaward
Landward
Volume Change (m³)
May02 - Aug02
Aug02 - Jan03
Jan03 - April03
17700
18000
18300
18600
18900
West
East
Distance Alongshore (m)

Figure 16



Grid Volume Change: 0 m Contour to -6 m Contour
PKS-IB Nourishment Zone
Volume Change (m^3)
Seaward
Landward
320000
240000
160000
80000
0
-80000
-160000
-240000
-320000
17700
17900
18100
18300
18500
18700
18900
May02 - Aug02
Aug02 - Jan/Feb03
Jan/Feb03 - April03
West
East
Distance Alongshore (m)

Figure 17

4.0 Examples of Data Products on CD

The value of high-resolution digital data, encompassed within a GIS database, is that it can be made readily accessible and can be tailored to fit the specific needs of various scientists, managers and the public. The accompanying CDs offer the opportunity for supplementing the above overview by giving access to the entire array of data in raw form and to specific data products that have not been discussed above. In the following paragraphs, we provide 1) an overview of how to access the GIS project, 2) the raw data file structure, and 3) and brief examples of data products that may be useful for particular applications.

The CD labeled “RAW Data” contains a directory called “BB_public_database” and a “ReadMe” file that briefly describes the data and contact information. The main directory is used to access all subdirectories of the raw data (“Year1_data”); select digital photos from each survey (“Year1_photos) and images of combined profile data (Year1_profiles_jpg”). The data directory is broken into subdirectories of each survey named by the month and year. Individual survey directories are broken into three parts that include “Beach_Tie”, “Marine_Tie” and “Profiles”. Individual data files in ASCII format for shore-normal and shore-parallel data can be found here. Each data file is named according to the type of data in that file and the date that it was collected. For example, a file named “BT01_041503_a” is the first in a series of Beach Tie lines that were collected on April 15, 2003 with the “a” signifying that the data has been adjusted for all necessary factors. Within each data directory is a folder that contains the complete metadata for each survey, meeting the Federal Geographic Data Committee metadata standard.

The CD labeled “GIS Database” contains one directory and three separate files. The directory called “Bogue_GIS” contains all the files in the GIS database. The text file called “ReadMe” explains all of the various products, file structure, instructions and contact information contained within the “Bogue_GIS” directory.

An application filed named “ae2setup” is a free viewer from ESRI software to navigate within GIS database for those who do not have ArcView 3.x or ArcGIS 8.x. The file named “bogue_yr1.apr” is the ArcView project file. There are specific instructions within the “ReadMe” file that describe how to load these files and where to put them if they are to be relocated from the CD to a computer hard drive.

The GIS project contains spatial data products that are overlaid on 1998 Bogue Banks digital DOQQs and separated into seven different views. Four of the views are specific to each survey date; they contain the MHW contour representing the shoreline position, merged topographic—bathymetric surface, and slope (Figure 18)

Figure 18. Example of the “survey” view detailing topography, bathymetry and MHW contour from April 2003.

The “shorelines” view contains each of the four quarterly MHW contours including a 5th shoreline derived from the August, 2000 LIDAR survey collected by NASA and USGS, and provided to us by the NOAA Coastal Services Center. Overlain on the May, 2002 shoreline are the color coded change data derived from the BeachTools transect locations described at the beginning of Section 3.1 These data have an associated attributes table that describes shoreline position change at each transect location and can be accessed through the identification tool in ArcView or the free browser (Figure 19).

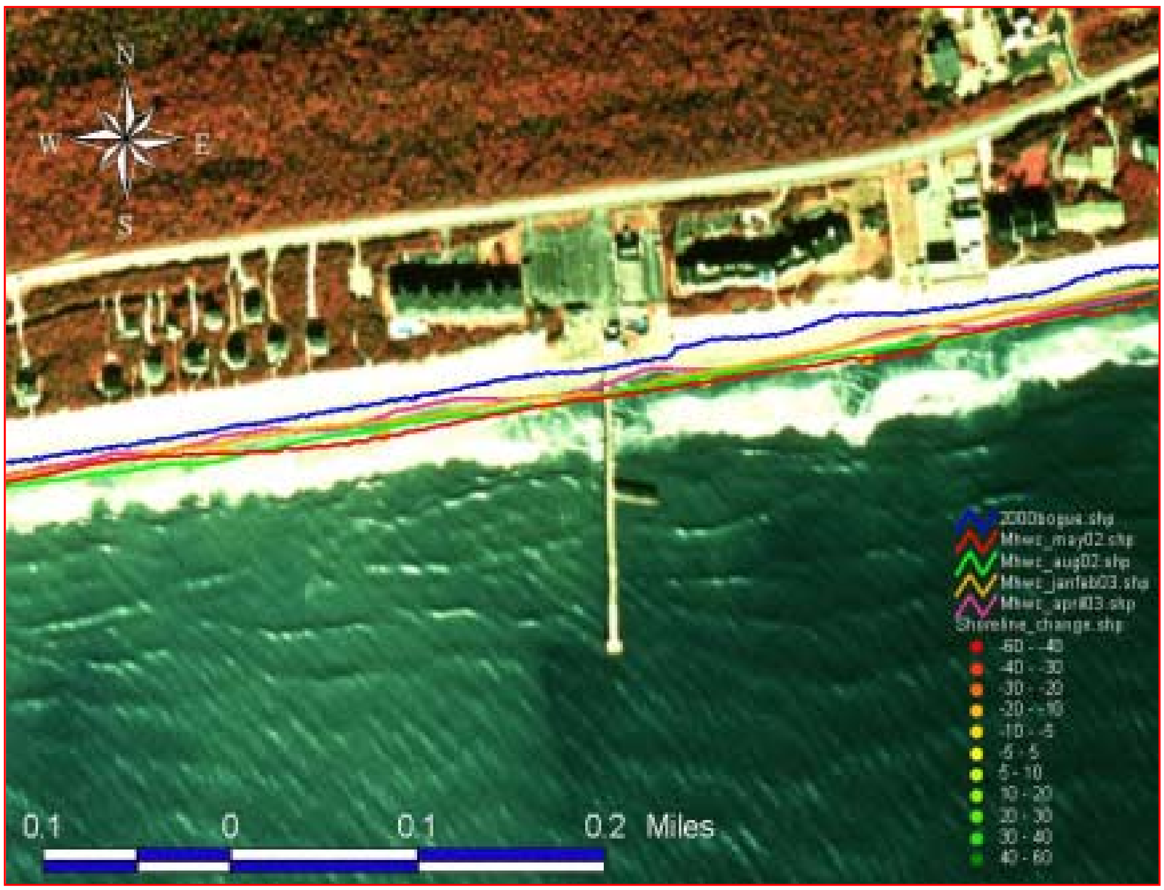


Figure 19. Example of the “shoreline” view illustrating each shoreline from the year 1 study and the accompanying change data.

The “change maps” view contains three change surfaces derived from each of the four quarterly surveys and two net change maps from the nourishment area (May, 2002—April 2003) and from the island wide surveys

(May, 2002—January 2003). These surfaces are generated by calculating the difference between each of the topographic and bathymetric grids (Figure 20).

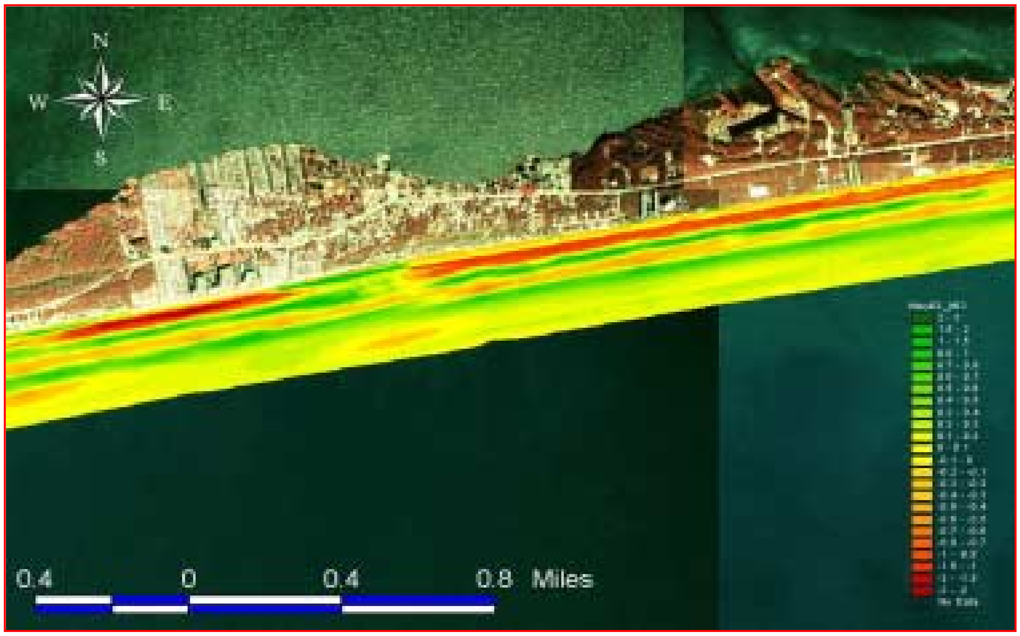


Figure 20. Example of the "change map" view showing the spatial extent of loss and gain within a particular segment of beach and nearshore.

Finally, the "survey design" view contains the county boundaries, regional shorelines, location of the profile transects, our GPS basestation positions and the National Geodetic Survey control for Carteret County (Figure 21).

Figure 21. Example of the "survey design" view detailing locations of survey control, profile locations and the Bogue Banks town boundaries.

5.0 Conclusions

1. Frequent collection of high-density beach and offshore data provides an effective tool for mapping morphologic change in the littoral system. Bogue Banks, which historically has been considered a stable barrier island with a relatively low rate of longshore sediment transport, displays far more variability and complexity than might previously have been assumed. Whereas the addition of nourishment sand during the winter of 2002 drastically altered the sediment budget on the island, and thus masked our ability to separate out many of the natural island-wide changes, it also provided a unique opportunity to gain insight into the equilibration process that follows beach nourishment.

2. When the shoreline, immediately after completion of the nourishment project (May, 2002), is compared to a pre-nourishment LIDAR survey in 2000, it is clear that most of the change *not* directly attributable to the nourishment project is within about 1.5 miles (2.4 km) of Beaufort and Bogue Inlets, where the shoreline has extended seaward up to +110 ft (~+34 m) at Bogue Inlet and +100 ft (~+30 m) at Beaufort Inlet (some of the change at Beaufort inlet is due to a 210,000 yd^3 disposal project during the winter of 2002). The shoreline along most of Atlantic Beach has moved seaward, and along most of Emerald Isle, except near Bogue Inlet, has moved slightly landward.

3. The island-wide changes in MHW position from May, 2002 - January, 2003, including those within the nourishment area, show a remarkable tendency to mirror those from LIDAR 2000 - May, 2002. Shoreline areas with previous seaward growth moved landward; areas with previous landward erosion moved seaward. These changes offer definitive evidence for significant sediment transport along and across the beaches of Bogue Banks. Without a full year of *island-wide* monitoring (and

preferably, multi-year monitoring) it is not possible to determine what percentage of this shoreline change is attributed simply to onshore-offshore exchange versus transport along the island.

4. The nourishment project resulted in an average seaward shoreline shift of +97.7 ft (+29.8 m) when compared to the LIDAR 2000 base survey. During our 1-yr observation period within this reach of the island, the shoreline moved landward an average of –27.9 ft (-8.5 m). Initial equilibration was highly variable, but was not especially fast (average –4.3 ft [-1.3 m]) except in the nourishment hole and just west of the project. Most of the equilibration occurred between August, 2002, and January, 2003, coinciding with the expected shift to a winter beach profile configuration. One of the more interesting observations was the partial return of shoreline position (average +9.8 ft [+3.0 m]) during the last quarter of our monitoring (January, 2003-April, 2003), generally coinciding with harshest conditions expected during an annual cycle.

5. Between the two island-wide surveys (May, 2002 and January, 2003) Bogue Banks experienced a net loss of –1.4 yd^3/ft (-3.5 m^3/m) from the beach and a net offshore gain of +6.1 yd^3/ft (+15.2 m^3/m). While unexpected, this apparent gain in sediment can probably be attributed to the addition of sand from “outside” sources, namely, input from dune erosion in Emerald Island and possibly from water depths greater than the –20 ft (-6 m) cutoff depth. The positive and negative offshore volume spikes at the west end of Bogue Banks can be attributed to the ebb tidal delta at Bogue Inlet.

6. As expected, loss of beach sand from the nourishment area over the course of the year, averaging –8.4 yd^3/ft (-21.1 m^3/m), was reflected in gains in the offshore area, averaging +5.4 yd^3/ft (+13.5 m^3/m). Quarterly survey data show that during the initial period of adjustment (May, 2002-

August, 2002) the western half of the project lost sediment from the beach while the eastern half actually gained sediment. The net change on the beach was +2.6 yd^3/ft (+6.4 m^3/m). Yet, during this same period virtually every offshore profile lost sediment (average –11.6 yd^3/ft (-29.1 m^3/m). As was the case with MHW contour data, the significant change in volume occurred between August, 2002 and January, 2003, coinciding with the onset of winter beach conditions. It was during this period that the average loss of beach sand (-9.3 yd^3/ft [-23.2 m^3/m]) and gain in offshore sand (+25.3 yd^3/ft [63.4 m^3/m]) were highest. The "budget" discrepancy between gains and losses opens up the possibility that there is considerable sand being exchanged across the –20 ft (-6 m) contour, and that considerable volumes of nourishment material may reside, unseen, in the water depths up to at least –30 feet. Multi-year surveys may be able to address the ultimate fate of this sediment.

6.0 Acknowledgments

The authors would like to express their gratitude to several groups and people who have made the Bogue Banks High-Resolution Beach and Nearshore Monitoring Year 1 project possible. We would like to thank Mike Forte for his field expertise, Dr. Jun-Yong Park for the development of and assistance with *Beach Profile Analysis Matlab Tools*, and Dr. Helena Mitasova for geostatistical advice and fine-tuning of our gridding algorithms. We would also like to thank the Sheraton Hotel and staff, the Summer Winds Condominiums, and the Crystal Coast Management & Consultants group for all their help in establishing and maintaining our survey basestation sites. Lastly, we would like to thank the Carteret County Beach Commission, the Carteret County Shore Protection office and the North Carolina Division of Coastal Management for funding.

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8.0 Table of Conversions

1 meter = 3.28 feet

1 foot = 0.305 meter

1 kilometer = 1,000 meters

1 mile = 1.61 kilometers

1 kilometer = 0.621 miles

1 cubic yard = 0.765 cubic meters

1 cubic meter = 1.308 cubic yards

1 cubic yard/ft = 2.5075 cubic meters/m

1 cubic meter/m = 0.3988 cubic yards/ft

Appendix A

Detailed Acquisition and Processing Methodology

Introduction

Scientists, engineers, and managers have long sought to quantify beach and nearshore morphology in order to understand the processes that influence a wide range of scientific and socio-economic issues. The importance of monitoring coastal morphology has become critical in recent years as populations within the US coastal zone expand; this growth creates additional demand for state and federal funding to protect coastal development, shoreline habitats, recreational beaches, and economies. In order to manage coastal resources effectively, managers require accurate and repetitive coastal surveys that provide insight into multi-scale trends of shoreline movement. In addition, these data also prove critical in calibrating predictive models of shoreline regression and storm surge, in the design and monitoring of beach nourishment, and in determining regional sediment budgets.

Ground-based topographic studies, utilizing two-dimensional (2-D) beach profiles, have typically been used to qualitatively and quantitatively describe morphology change (Emery 1961; Leatherman 1983; Nelson 1991; Weggel 1995). Although repetitive shore-normal profiles accurately describe morphology change at discrete locations and are critical for historical change analysis, using traditional 2-D profiles to describe the true three-dimensional (3-D) morphology assumes little variation in the alongshore direction (Swales 2002). Many of the complex spatial variations observed between profiles, such as “hotspots” of erosion or accretion, beach cusps or interrupted sandbars, may not be captured within a series of profiles; this is especially true in studies where the surfzone and offshore region (to local closure depth) are ignored. Accurate assessments of 3-D coastal morphology require a high density of topographic and bathymetric data points that can be merged at the land/water interface to make accurate models with which to analyze spatial and temporal variability.

High-density collection techniques, such as LIDAR and swath bathymetry, are clearly ideal to accomplish accurate 3-D mapping. However, these high-resolution technologies are expensive to operate and therefore may not be practical along small segments of beach/nearshore (i.e. <25 mi; <40km) or at the high temporal resolutions necessary to understand short- and long-term trends. Advances in Geodetic Global Positioning Systems (GGPS) technology and shallow water sonar have allowed our group to rapidly and accurately collect a high-density of spatial data for a fraction of the time and cost of other techniques. 3-D models of the beach, surfzone and nearshore can then be generated with significantly reduced error by using these high-density data collection techniques. Modeled topographic and bathymetric surfaces can then be used to calculate various parameters, such as elevation, volume, slope, and curvature, and for the extraction of datum derived shorelines. These various raster-based surfaces and extracted vector-based shorelines, served from a geostatistical GIS database, can further be used to create a time series of change along any segment of the beach or nearshore that is of interest (see enclosed GIS project CD).

Acquisition

The acquisition method employed for the Bogue Banks monitoring project takes advantage of GGPS technology coupled with Real-Time Kinematic baseline processing (RTK-GPS) and motion-compensated, shallow-water sonar. An important advantage of this method over traditional beach surveying methods is the greater spatial coverage that can be achieved along the beach, surfzone and nearshore regions. This is accomplished by running parallel survey lines along the beachface and surfzone out to the –10 m isobath. These “tie-lines” are then merged with traditional cross-sectional profiles collected from the dune out to –33 ft (–10 m), which overlap within the surfzone (Figure 1).

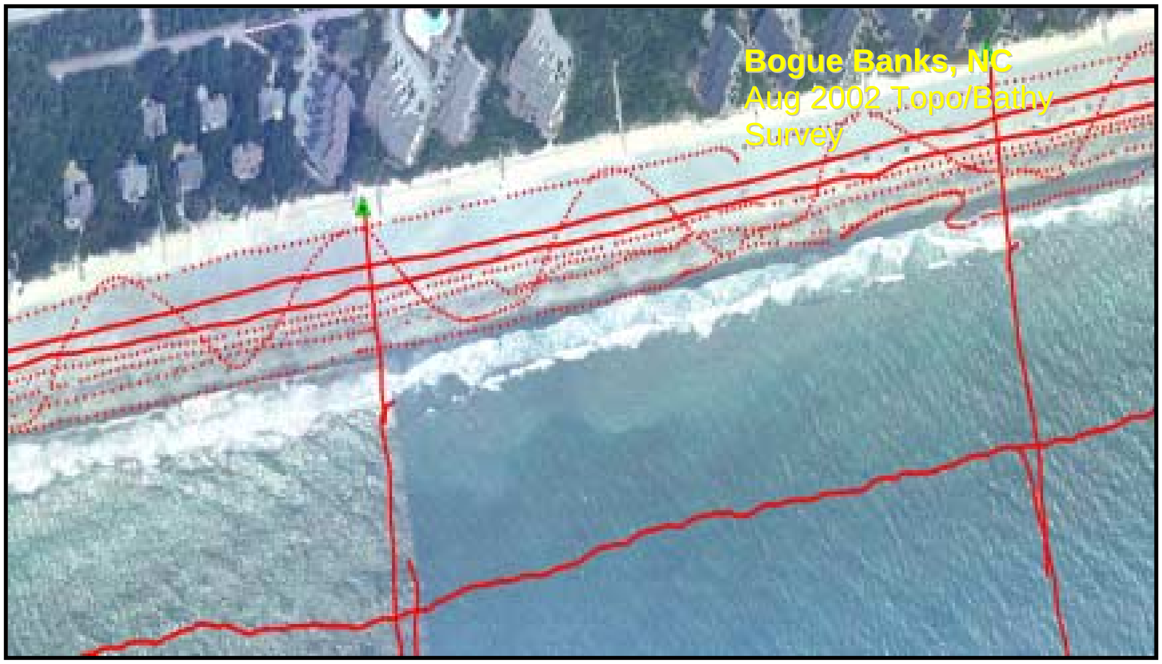


Fig. 1. Survey track lines showing 1Hz (dots) and 5Hz/200kHz (solid) data and the alongshore

To facilitate this high-density data acquisition method, we use vehicle-assisted instrument platforms on the beach and offshore. The terrestrial acquisition system consists of two all terrain vehicles (ATV) equipped with Trimble 4700 and Ashtech Z-surveyor RTK-GPS rover systems (Figure 2a). One ATV is dedicated to the collection of profile data, which are digitally navigated and the second ATV collects the shore parallel lines along breaks in morphology. These morphologically based lines more accurately represent the true morphology when processing the spatial data (Figure 3). Shore-normal profiles (on planned lines) are navigated on foot from the top of the dune out to wading depth at the lowest possible tide using HYPACK Max v.005a surveying software. Obtaining these profiles during low tide ensures complete overlap with the hydrographic survey in the surfzone. The hydrographic segment of our acquisition system makes use of an 18 ft (5.6 m) rigid hull inflatable boat (RHIB) powered by jet drive (Figure 2b). The instrument array on the RHIB consists of a Marimatech survey-grade single-beam echosounder for the collection of seafloor elevations, an RTK-GPS for positioning and tidal corrections, and a TSS DMS-05 motion reference sensor for heave, pitch and roll calculations. HYPACK Max v.005a surveying software is used to integrate these instruments and to aid in the post-processing of the hydrographic data stream.

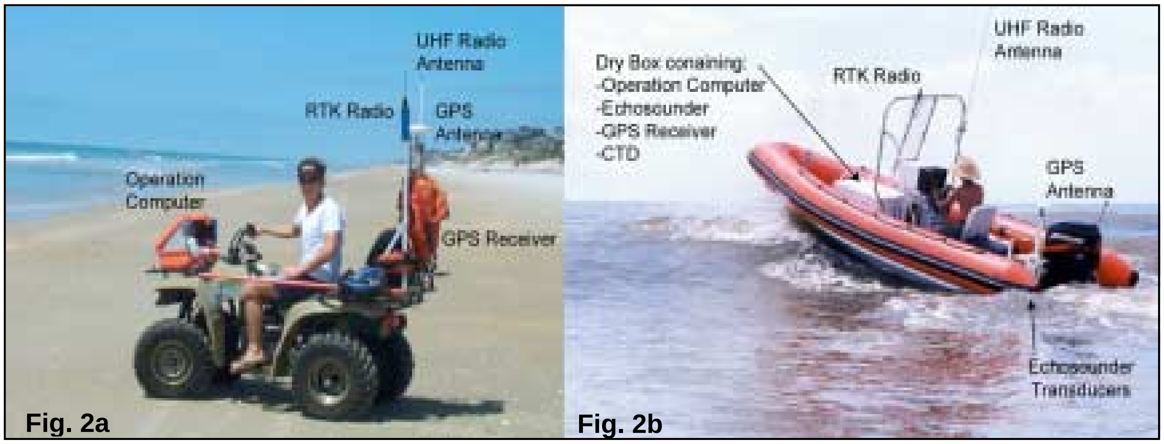


Fig. 2. Real-Time-Kinematic Global Positioning System (RTK-GPS) mounted on an all-terrain vehicle (a) for acquisition of subaerial beach data. Nearshore survey vessel equipped with single beam sonar, RTK-GPS and motion reference unit.

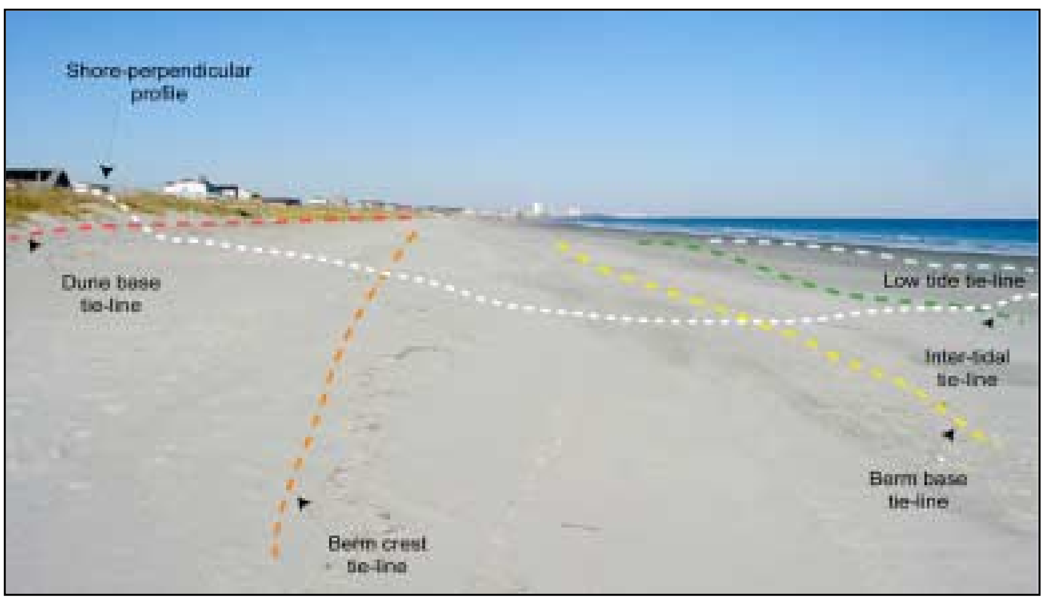


Fig 3. Beach survey lines based on morphology breaks.

Survey Accuracy

The accuracy of these mapping techniques was studied through a series of tests to determine the error range of terrestrial data collected with “RTK on-the-fly” versus “RTK fast-static”, and for bathymetric data that used RTK for tidal correction. Twelve, first-order horizontal and second-order vertical, National Geodetic Survey (NGS) benchmarks were occupied from the three basestations established along Bogue Banks. Each benchmark was surveyed in an RTK site calibration mode that collects baseline solutions over a 3 to 8 minute occupation time. This test is used to evaluate the horizontal and vertical accuracy of our basestations, establish the relationship between WGS-84 and the North Carolina State Plane coordinate system, and to assess the local geoid/spheroid separation. Results from this test show that our average vertical error for the site calibration was 0.48 in (1.22 cm) (Figure 4) and that horizontal errors are on average 0.4 – 1.2 in (1 cm to 3 cm).

The site calibration gives us valuable error information; however to more accurately assess the potential field error we occupied the same twelve benchmarks and collected “rapid points” at 1Hz. This exercise simulates point collection in a continuous topographic mode as we would acquire them in the field. The “rapid point” experiment shows an average elevation error of 1.68 in (4.28 cm); however, we expect to see a range of error in the field due to daily environmental factors (see Morton *et al*., 1993). To account for these daily error factors we have established the range of terrestrial error for the Bogue Banks project to be approximately 0.4 in (1 cm) to 2.8 in (7 cm) (Figure 4). This

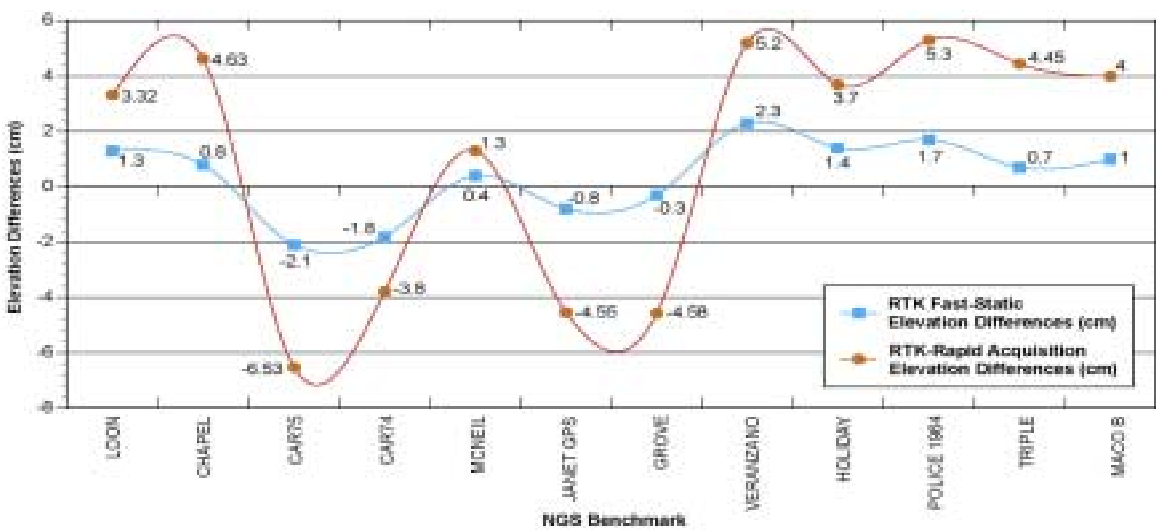


Fig. 4. Elevation difference (ΔZ) between the NGS benchmarks (0) and error analyses at Bogue Banks.

elevation range is applied to our sonar-based acquisition system that makes use of the RTK signal for computing tidal heights. Currently, the International Hydrographic Organization (IHO) maintains errors should not exceed 1 ft (30 cm) for shallow water surveys (IHO 1987); however, our bathymetric surveys are accurate to <4 in (<10 cm) due to RTK-derived tidal corrections and rigorous calibration.

There are many environmental and operator-based influences that affect the accuracy of RTK-GPS systems and the resultant baseline solutions (Morton et al. 1993; Bilker 2001; Trimble Navigation Limited 1998; Magellan Corporation 2001). Although RTK-GPS has become a popular tool with surveyors and hydrographers, little attention has been given to accuracy standards of this method, especially in the field of coastal mapping (Morton *et al*., 1993). We have used this experiment and standards templates from the California Dept. of Transportation, the International Hydrographic Organization and the US Army Corps of Engineers to develop an internal standards protocol for error acceptance and error estimation for project design and data acquisition (CALTRANS, 2002; IHO, 1987; USACE, 2002). Consequently, any acquired data that falls above 10cm in vertical and horizontal error is flagged and ultimately unaccepted.

3D Surface Processing

Processing these data begins with a high order quality control procedure of the raw position and elevation data. The raw sonar and elevation data is first corrected for various motion, tidal and daily error parameters through Hypack Max software. After the first order processing, the data is run through a custom MATLAB program called Beach-profile Analysis MATLAB-tool (BAM) designed by our work group to not only process these unique datasets but also to analyze redundant points, sonar spikes, draft correction errors and general data inconsistencies (Park 2002). The marine and terrestrial data are then merged in

BAM, analyzed a third time for similar parameters and then made available for 3D interpolation.

Once the data are completely free of error, we use the spatially dense points to create digital elevation models (DEMs) of the study area. Processing these data, representing shoreline topography and nearshore bathymetry with strong anisotropy, provides a unique challenge (Mitasova *et al*. 2003). While density of points along the marine and terrestrial survey lines is very high 0.30-0.90 ft (1-3 m) apart, for practical reasons the distance between paths can be tens to hundreds of meters apart especially in the offshore regions. To preserve most of the detail captured along each path and at the same time minimize the artifacts commonly created by interpolation functions between paths, we use a *Regularized Spline* or *Kriging* function with anisotropic tension and optimized parameters to create 3D surface representations of the study area (Mitasova *et al*. 2003).

Surface generation for the Bogue Banks Year 1 study makes use of the linear *Kriging* algorithm in Surfer 8 software as a result of its flexibility and capacity to de-trend highly anisotropic data (Mitasova *et al*. 2003). A grid-cell size of 16 ft (5 m) was used for interpolating each of the surfaces and a trend angle of 60 degrees, which corresponds with the preferred orientation of the data, or alongshore coastline orientation from true north. A search radius of 27.7 ft by 9.5 ft (91 m by 31 m) with an anisotropic ratio of 3 was selected in order to account for the high density of data points along the survey track lines and the lack of complete coverage between survey lines. Finally, each surface was clipped with a common masking file to eliminate regions where no data exist, reduce interpolation artifacts and allow each surface to be comparable to one another (reference Bogue Banks GIS project file on enclosed CD).

The modeled grid surfaces are used to calculate various parameters associated with the beach and nearshore including: elevation, volume, slope, curvature and the extraction of datum derived shorelines. A series of rasterized grids and extracted shoreline vectors are compared to one another in a GIS-based geostatistical software package to create a time series of change. We can then create and query a variety of change maps to quantify morphological trends such as “hotspots” of erosion/accretion, along- and cross-shore sediment transport, renourishment performance/evolution, along with a variety of additional analyses germane to that segment of coast.

DISCUSSION

Accurate 3-D modeling of beach and nearshore morphology is a function of the data density with which the models are based. Clearly, acquisition techniques such as LIDAR or swath bathymetry have the ability to provide the density of data required for accurate 3-D mapping. However, the costs associated with collection of these data are generally prohibitive for projects that require high frequency monitoring (i.e. quarterly or monthly) over a relatively short distance (i.e. <25 mi or <40 km). In addition, the surfzone is often ignored with these techniques due to water clarity for LIDAR systems and the size of vessel required for swath bathymetry. Yet it is well known that the surfzone can retain considerable volumes of sediment, which are periodically released to the beach in fair weather or stored in offshore sandbars during storms. Frequent volume and bar configuration measurements in the surfzone and beachface are necessary to ultimately understand beach and nearshore morphology.

Traditional 2-D techniques that measure elevation along a shore-normal line from the dune out to varying depths remain valuable because they allow for important historical comparisons. However, interpolation routines that perform numerous calculations of beach and nearshore parameters between profiles spaced 100’s of feet apart assume little variation in the alongshore. As a result, the resolution is usually too coarse to resolve geomorphic patterns, identify local “hotspots” of erosion and accretion, or measure the true volume change over time with some amount of accuracy (Figure 5).

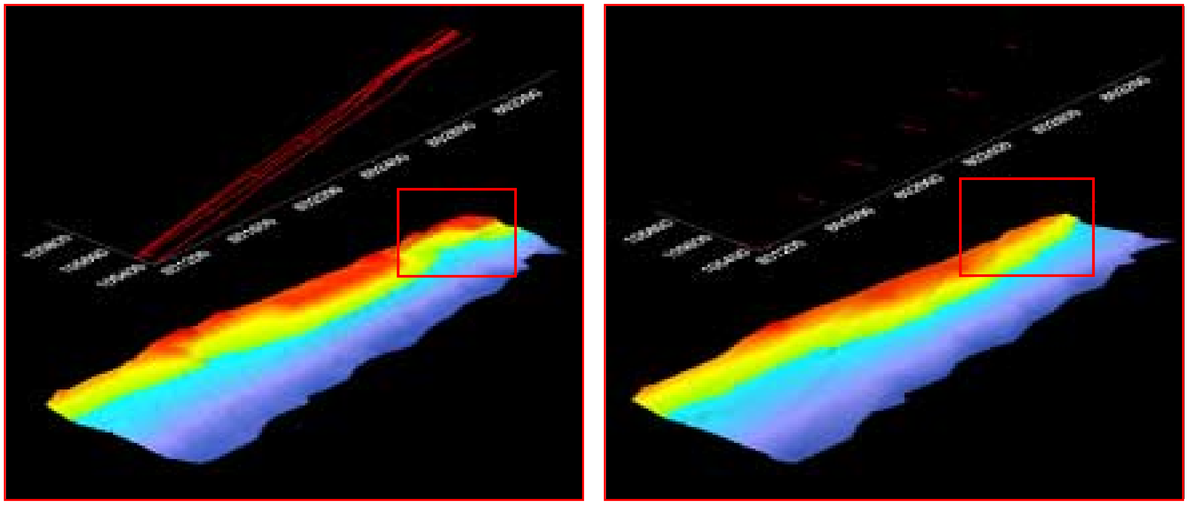
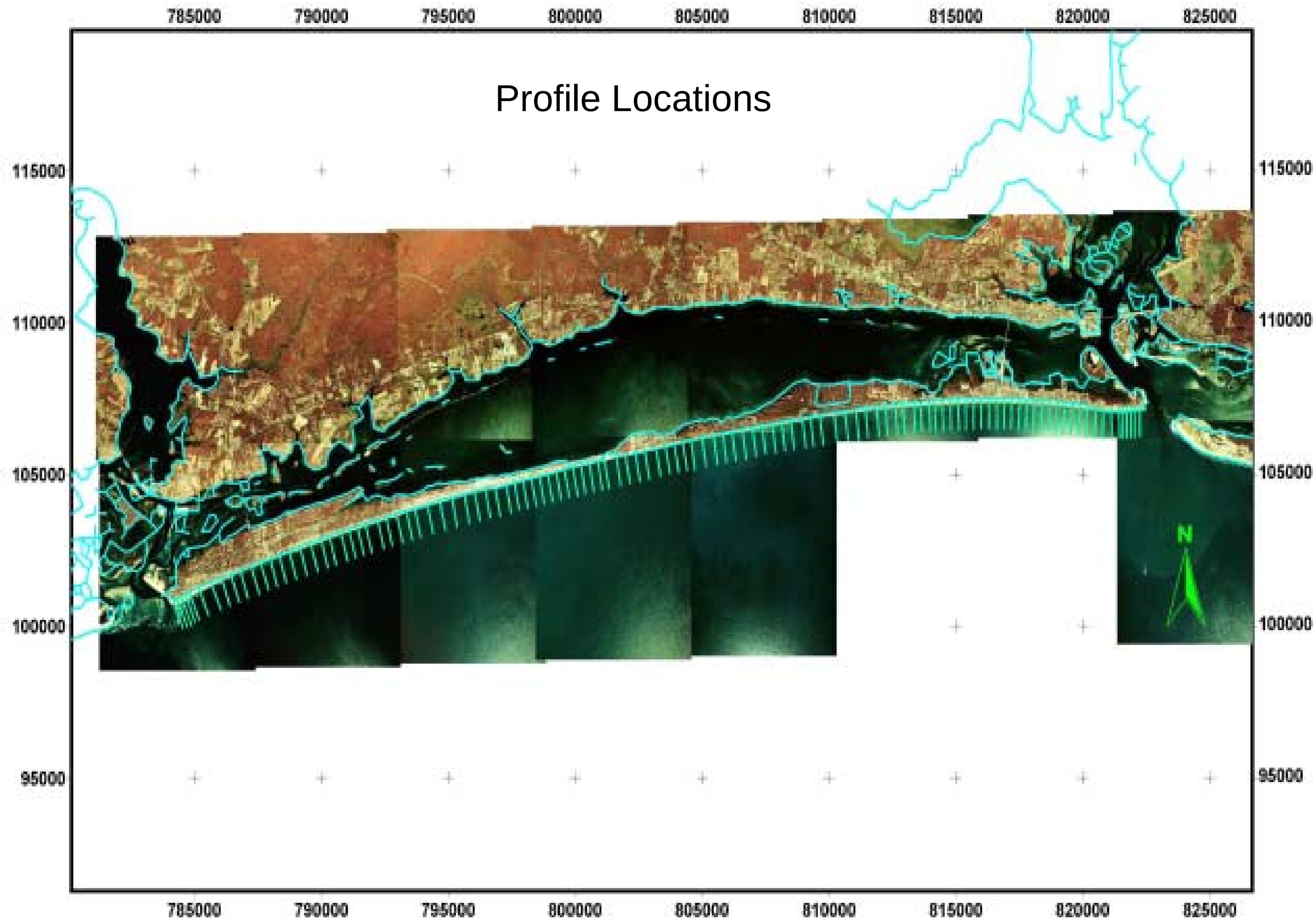


Fig. 5. Gridding experiment from data collected at the “hole” region along a 2.5 km stretch of Indian beach. Image A shows a 3-D model based on all shore normal and shore parallel data. Image B shows the same stretch of shoreline however the 3-D model used only profile data to generate the grid. The volume difference between the two zones was approximately 7700 m^3.

To take advantage of 3-D analysis without the expense of swath-based systems and without the limitations of 2-D methods, we argue that a ground-based technique which combines traditional shore-normal profiles with alongshore data is optimal for small scale, high frequency monitoring. Using these and other experiments we were able to determine the optimal survey design configuration and data specific interpolation routine required to accurately evaluate the beach and nearshore in three dimensions. By coupling an RTK-GPS system with an all terrain vehicle and a shallow-water, sonar-equipped vessel, it is possible to achieve centimeter-scale horizontal and vertical precision while traversing the beach and surf zone at speeds of 3-5 mi/hour (5-8 km/hour). The integration of acquisition and processing techniques allows our team to quickly capture important geologic features (i.e. beach cusps, dune erosion, scarps and sandbars) and, over successive surveys, capture trends that would have otherwise been missed.

Appendix B

Beach/Offshore Profile Volumes and Images


Profile Locations
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790000
795000
800000
805000
810000
815000
820000
825000
115000
110000
105000
100000
95000
N

May 2002 to January/February 2003

Bogue Banks

Profile #	May02-Jan/Feb03 Beach (m^3/m)	May02-Jan/Feb03 Offshore (m^3/m)	Profile #	May02-Jan/Feb03 Beach (m^3/m)	May02-Jan/Feb03 Offshore (m^3/m)
1	-23.11	-254.00	29	-5.43	57.64
2	7.53	36.90	30	-11.48	44.48
3	-23.57	197.25	31	9.07	53.05
4	no data	no data	32	-1.65	39.71
5	6.03	-24.20	33	-1.51	48.82
6	16.06	-59.93	34	-6.80	34.67
7	1.23	21.15	35	-2.77	35.52
8	1.59	-6.96	36	1.01	21.84
9	0.02	-11.19	37	2.64	78.48
10	9.88	4.97	38	5.34	49.25
11	11.48	20.23	39	-1.21	38.55
12	16.63	35.52	40	-1.19	35.35
13	2.20	19.58	41	-4.34	32.51
14	10.32	20.85	42	-1.88	34.67
15	15.38	32.77	43	-1.10	42.64
16	9.46	39.01	44	0.23	47.67
17	9.66	34.21	45	1.05	46.33
18	8.35	14.85	46	-0.35	46.85
19	-10.98	2.72	47	3.53	27.44
20	8.27	19.79	48	7.46	53.48
21	8.26	25.41	49	8.18	8.34
22	-5.49	34.98	50	-46.86	39.17
23	-17.91	9.16	51	-56.43	42.72
24	-1.35	46.68	52	-9.82	84.30
25	-5.07	77.89	53	16.29	56.02
26	-2.47	61.14	54	-43.47	68.57
27	-6.41	60.32	55	-43.11	77.80
28	-1.13	44.46	56	-34.18	69.71

May 2002 to January/February 2003

Bogue Banks (cont.)

Profile #	May02-Jan/Feb03 Beach (m^3/m)	May02-Jan/Feb03 Offshore (m^3/m)	Profile #	May02-Jan/Feb03 Beach (m^3/m)	May02-Jan/Feb03 Offshore (m^3/m)
57	-32.60	70.95	**85**	4.07	61.32
58	-32.93	78.57	**86**	-0.37	-61.81
59	-31.91	60.47	**87**	-2.13	-15.40
60	-25.68	53.02	**88**	7.47	45.43
61	-23.43	34.25	**89**	6.25	7.16
62	-23.79	50.55	**90**	24.11	-24.88
63	-27.69	69.87	**91**	16.54	-1.47
64	-14.58	80.95	**92**	9.77	-18.07
65	-10.98	56.00	**93**	14.26	-46.58
66	4.08	75.57	**94**	16.16	13.97
67	-36.61	-70.03	**95**	12.64	19.69
68	-20.63	-13.77	**96**	-13.92	-18.22
69	7.87	29.11	**97**	12.59	-11.41
70	10.95	-5.41	**98**	5.39	2.81
71	-1.91	23.19	**99**	13.13	-162.76
72	-16.66	-74.99	**100**	no data	26.66
73	-20.71	-44.57	**101**	19.07	-8.66
74	-16.34	-102.37	**102**	3.51	-76.55
75	-3.18	33.05	**103**	22.61	-66.99
76	8.70	60.64	**104**	-16.75	-36.06
77	-1.40	34.66	**105**	-23.70	-80.35
78	16.49	2.12	**106**	no data	-25.14
79	15.77	16.91	**107**	-15.45	-15.90
80	9.99	-5.07	**108**	-11.68	-31.19
81	8.97	-10.35	**109**	4.52	-104.12
82	15.31	29.44	**110**	-8.15	-33.12
83	0.51	-30.93	**111**	-62.62	-6.86
84	1.34	13.71			

May 2002 to August 2002

PKS-IB Nourishment Zone

Profile #	May02-Aug02 Beach (m^3/m)	May02-Aug02 Offshore (m^3/m)
45	2.66	-18.59
46	6.14	-52.45
47	24.45	-21.04
48	43.74	-42.91
49	-15.30	-46.32
50	-22.92	-53.19
51	12.99	-40.44
52	34.72	-14.15
53	-3.32	-27.64
54	-4.15	-20.31
55	4.87	-19.87
56	0.67	-45.65
57	-9.38	-3.94
58	-2.20	-30.65
59	-1.07	-44.37
60	-8.38	-30.45
61	-2.32	-32.15
62	-5.78	-17.18
63	-1.51	-3.20
64	-4.71	-26.50
65	28.25	-18.44
66	3.96	-69.60
67	6.92	-72.10
68	22.03	15.33
69	11.98	-66.55
70	11.24	-45.99
71	15.52	-11.70
72	0.85	-6.39
73	13.23	-63.71
74	22.69	26.18
75	22.24	-28.72
76	25.34	-35.40
77	30.43	-29.83
78	20.74	-12.47
79	10.68	-29.94
80	18.09	-9.36
81	22.10	10.16

August 2002 to January/February 2003

PKS-IB Nourishment Zone

Profile #	Aug02-Jan/Feb03 Beach (m^3/m)	Aug02-Jan/Feb03 Offshore (m^3/m)
45	-3.00	65.43
46	-2.43	80.49
47	-16.79	75.12
48	-35.34	51.85
49	-31.36	86.08
50	-33.25	96.51
51	-22.62	125.34
52	-17.99	71.37
53	-40.15	89.01
54	-38.72	98.71
55	-38.83	90.17
56	-32.81	117.81
57	-23.55	82.51
58	-29.71	91.12
59	-24.14	98.59
60	-14.84	65.31
61	-21.47	82.69
62	-21.91	87.04
63	-13.07	84.15
64	-6.27	82.50
65	-24.17	94.01
66	-42.28	-3.42
67	-27.56	58.32
68	-13.87	14.37
69	-0.81	61.74
70	-12.75	70.38
71	-32.18	-63.29
72	-21.56	-38.18
73	-29.57	-38.66
74	-3.18	33.05
75	-13.33	89.96
76	-26.52	70.66
77	-13.50	33.15
78	-4.45	30.58
79	-0.48	25.47
80	-9.12	-0.99
81	-6.56	19.89

January/February 2003 to April 2003

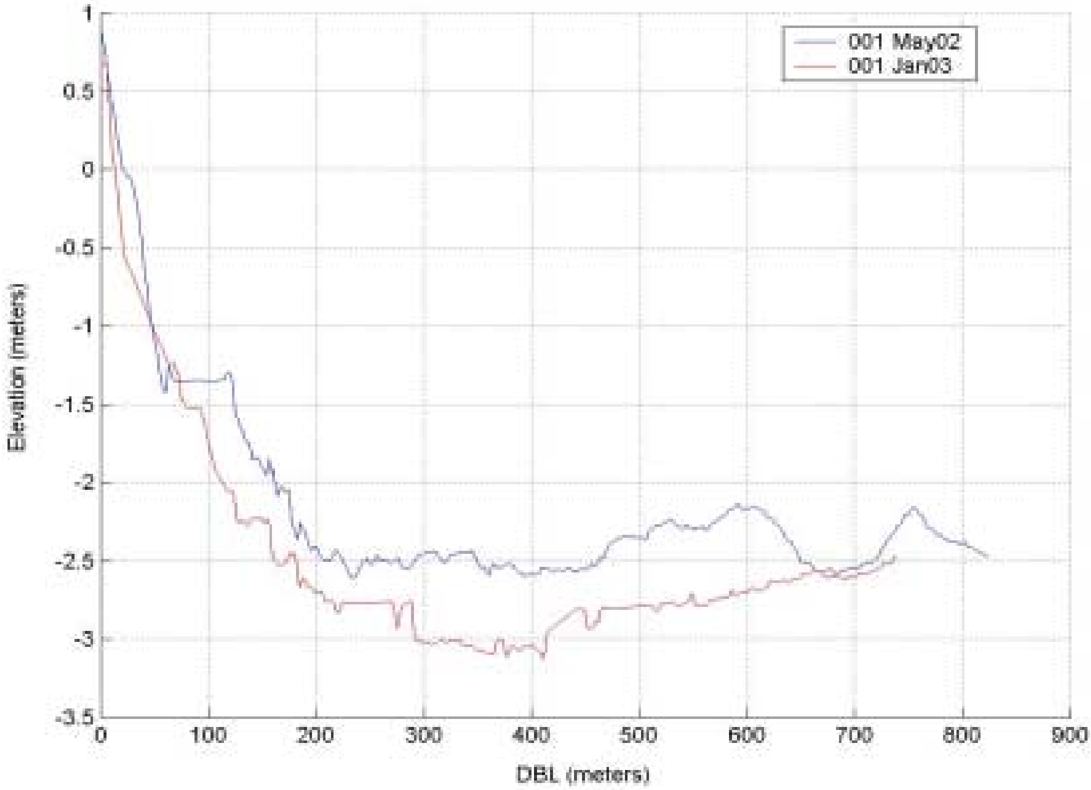
PKS-IB Nourishment Zone

Profile #	Jan/Feb03-April03 Beach (m^3/m)	Jan/Feb03-April03 Offshore (m^3/m)
45	90.20	120.60
46	61.92	93.99
47	47.31	132.65
48	-5.62	14.48
49	-10.52	-4.68
50	-12.04	13.18
51	-10.61	-6.68
52	-12.19	-37.65
53	-8.31	-21.25
54	-5.64	-47.24
55	-2.97	-15.97
56	-6.82	-63.10
57	-8.43	-41.36
58	-10.67	-69.60
59	-6.96	-39.24
60	-7.05	-31.37
61	-5.65	-45.62
62	2.61	-42.94
63	2.41	-68.87
64	-3.39	-34.92
65	-12.74	-82.56
66	-4.87	-2.70
67	10.46	-7.61
68	-13.01	-33.60
69	-2.44	-10.42
70	13.48	-37.01
71	-4.60	57.27
72	1.03	56.64
73	-4.79	116.38
74	0.70	-57.26
75	2.76	-28.37
76	6.72	18.02
77	-3.29	38.97
78	-2.73	-1.05
79	1.12	21.61
80	0.74	-5.04
81	-17.10	-21.28

May 2002 to April 2003

PKS-IB Nourishment Zone: Year 1

Profile #	May02-April03 Beach (m^3/m)	May02-April03 Offshore (m^3/m)
45	91.49	172.25
46	65.83	122.64
47	55.79	189.13
48	2.96	24.02
49	-56.09	38.09
50	-68.23	56.51
51	-19.41	80.62
52	4.11	18.37
53	-51.78	40.12
54	-48.75	30.56
55	-36.36	56.13
56	-39.42	7.86
57	-41.36	37.21
58	-40.90	-4.93
59	-31.56	16.78
60	-30.48	2.88
61	-28.60	7.33
62	-25.08	26.93
63	-11.93	12.69
64	-13.18	24.08
65	-8.41	-6.39
66	-41.48	-72.73
67	-10.18	-21.39
68	-3.08	-0.29
69	10.29	-11.02
70	11.56	-13.82
71	-20.61	-15.92
72	-18.88	14.47
73	-20.86	14.62
74	-1.02	-20.01
75	11.46	32.28
76	5.32	52.68
77	13.41	41.69
78	13.31	16.46
79	11.33	17.14
80	11.30	-11.19
81	-0.47	11.76



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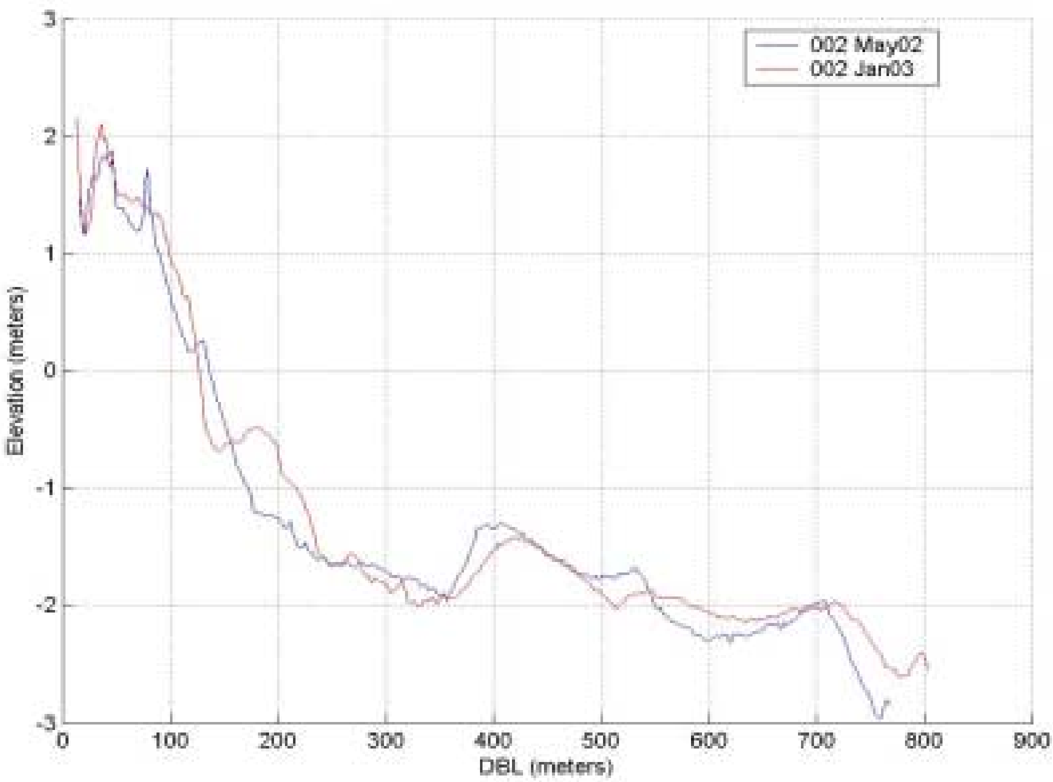
DBL (meters)



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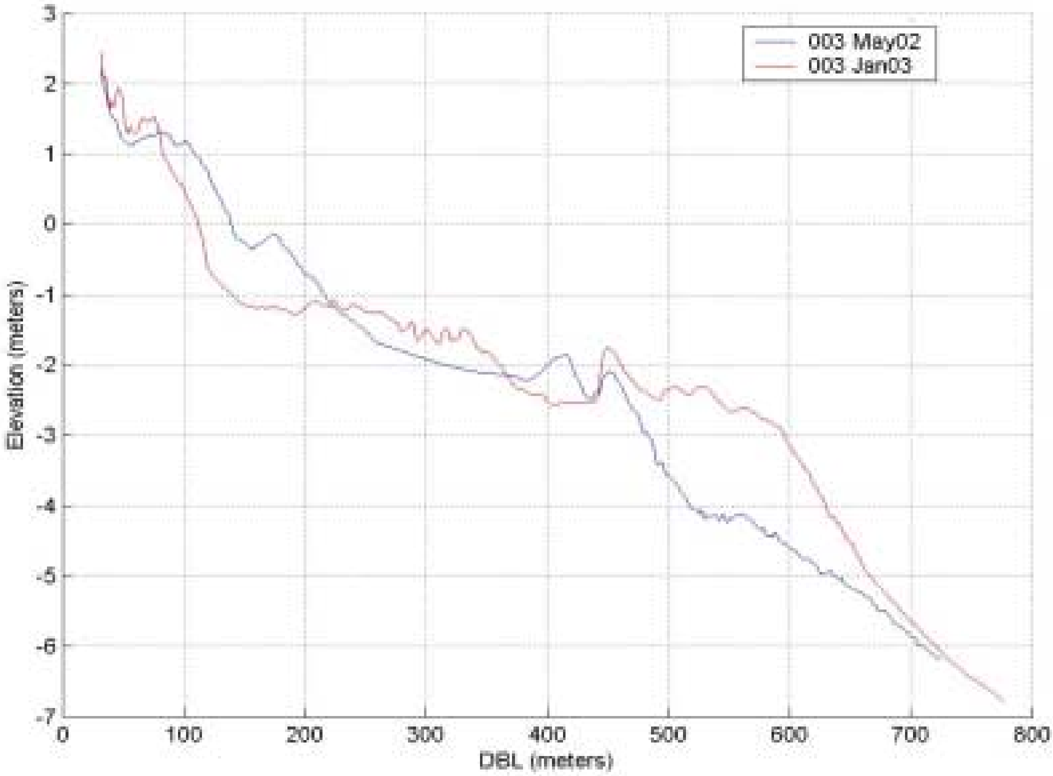
DBL (meters)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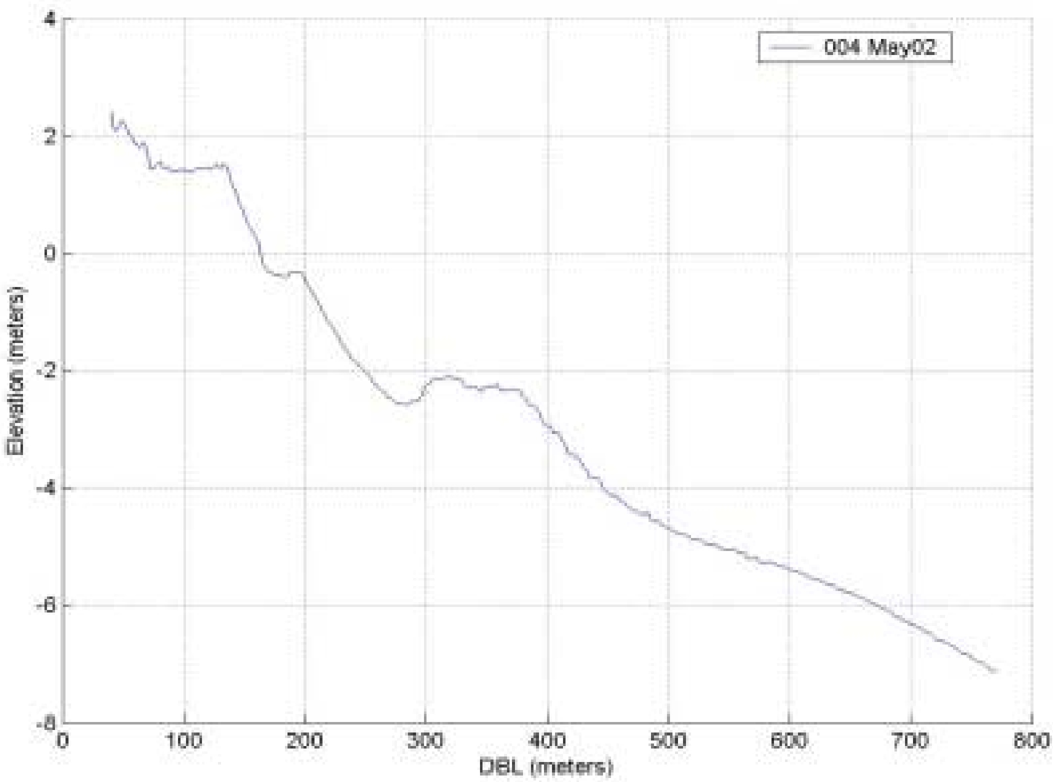
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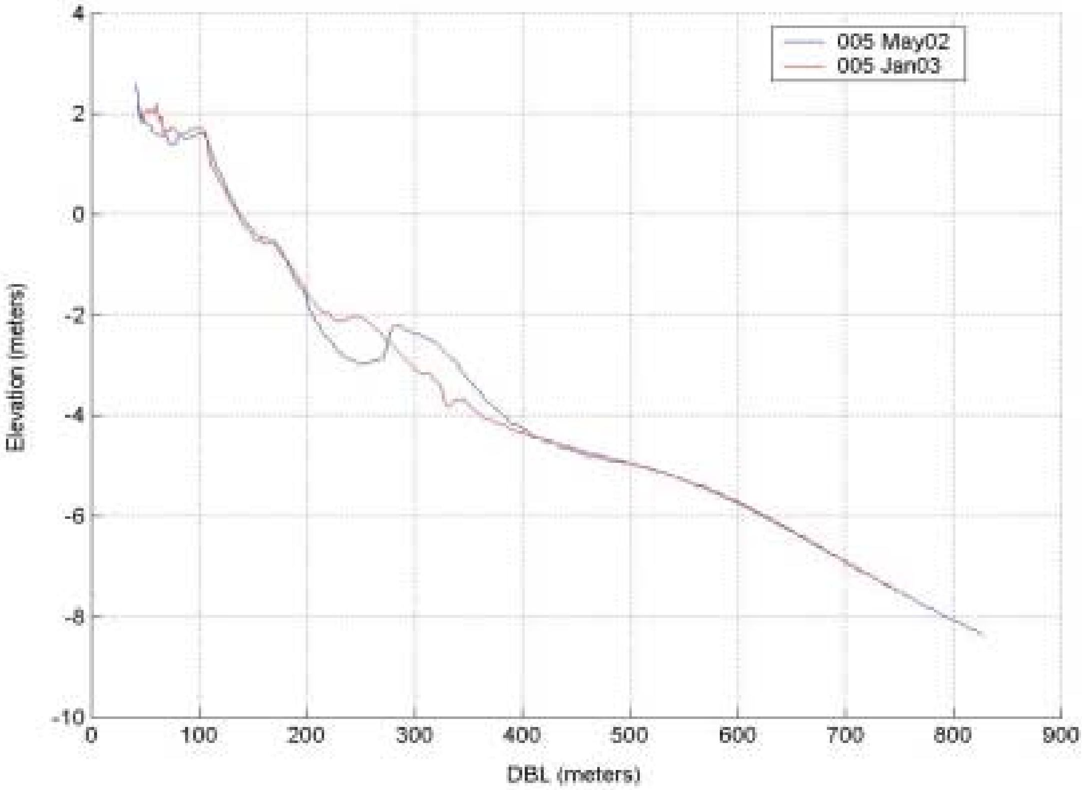

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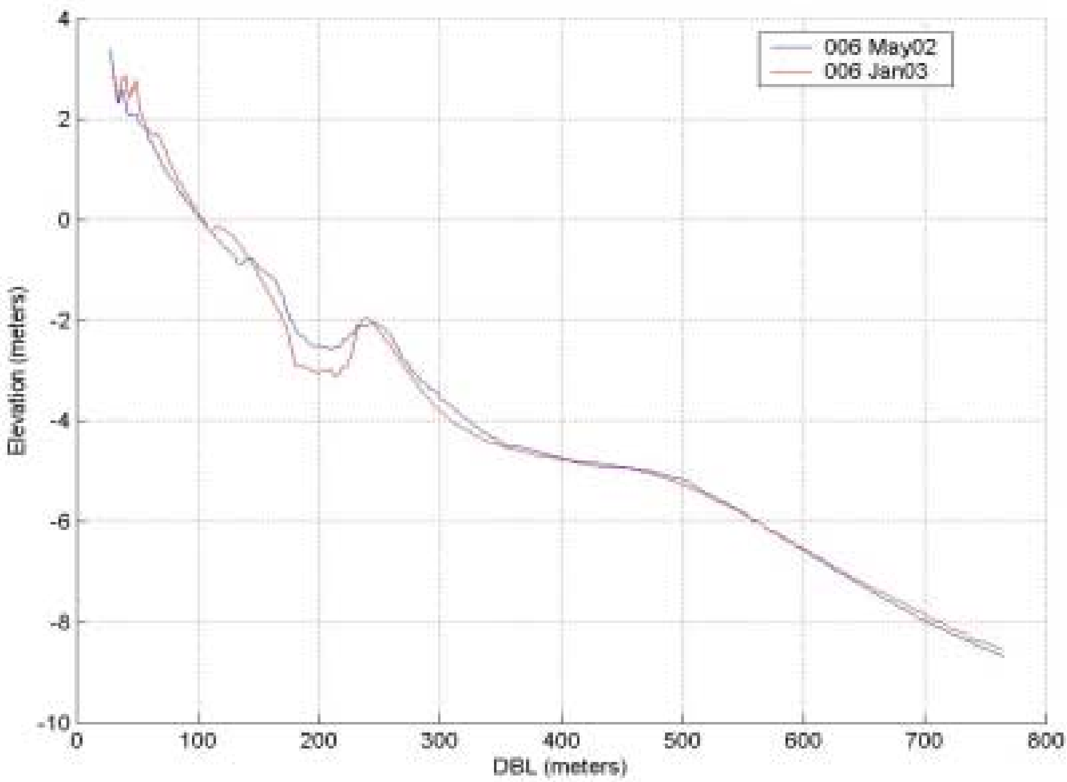
DBL (meters)



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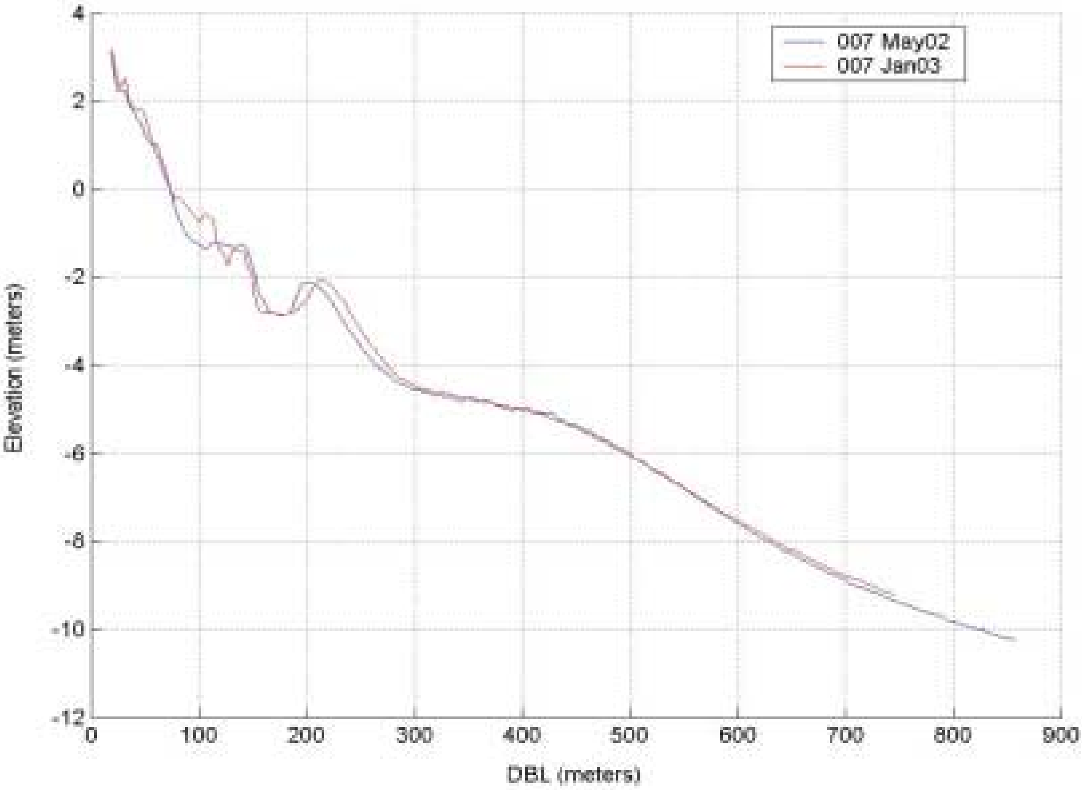
DBL (meters)



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DBL (meters)
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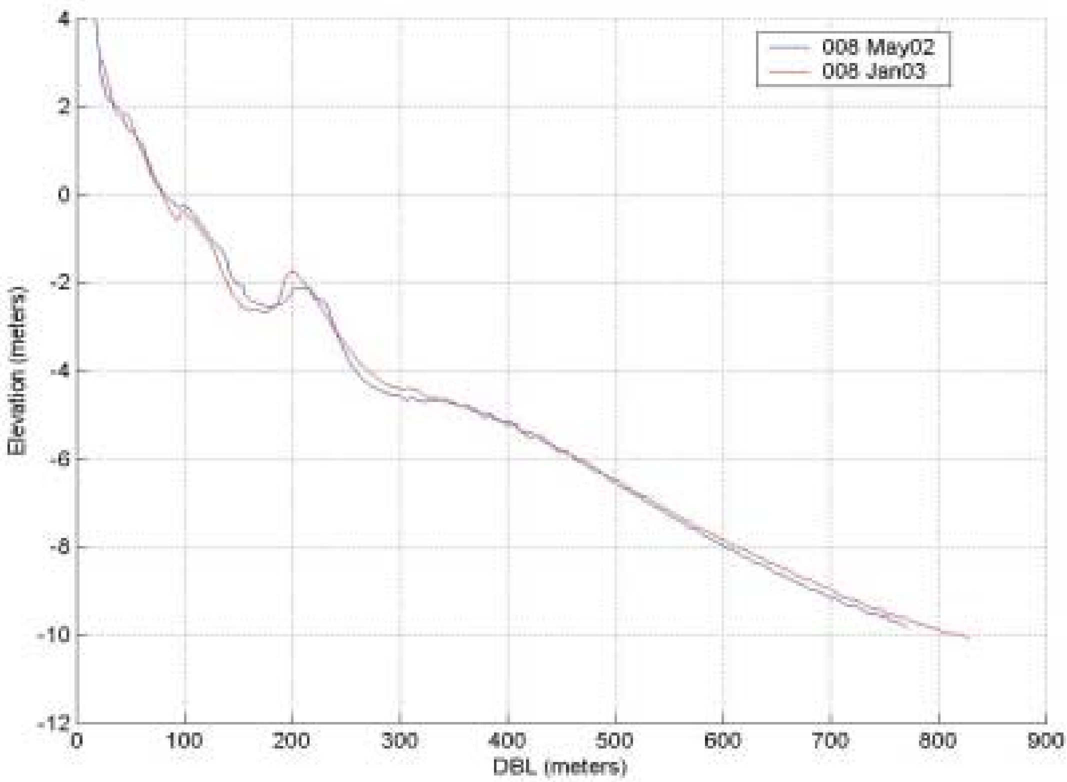

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DBL (meters)
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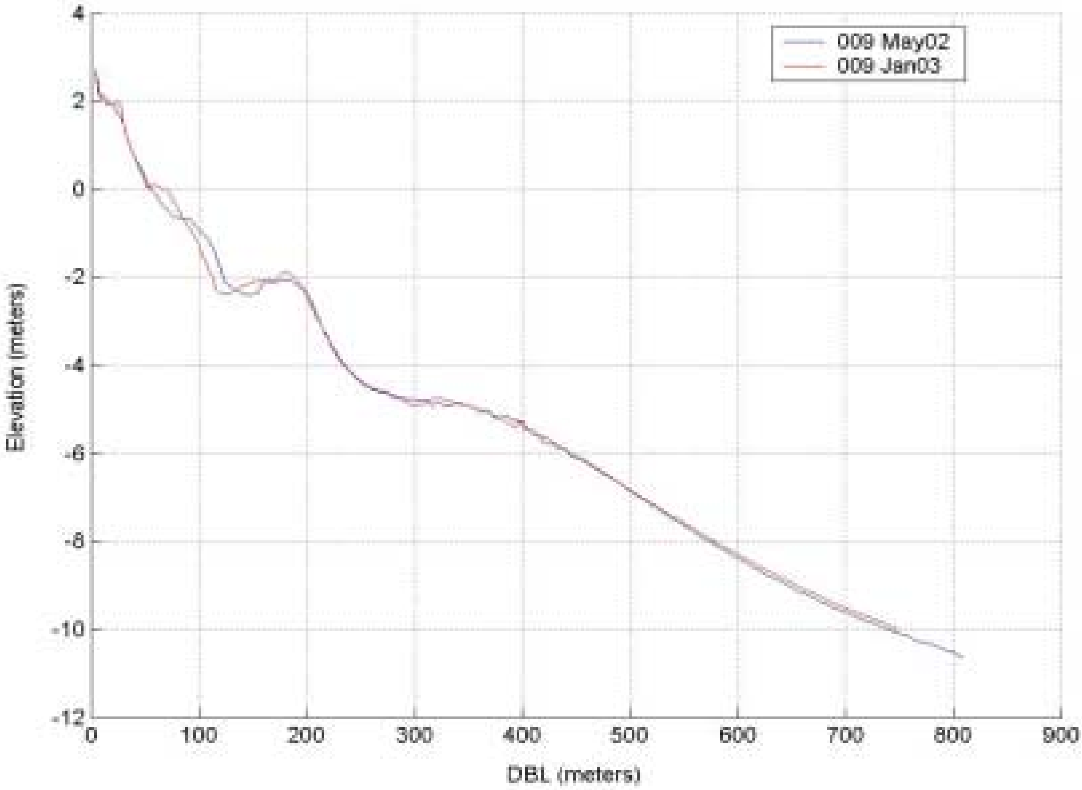
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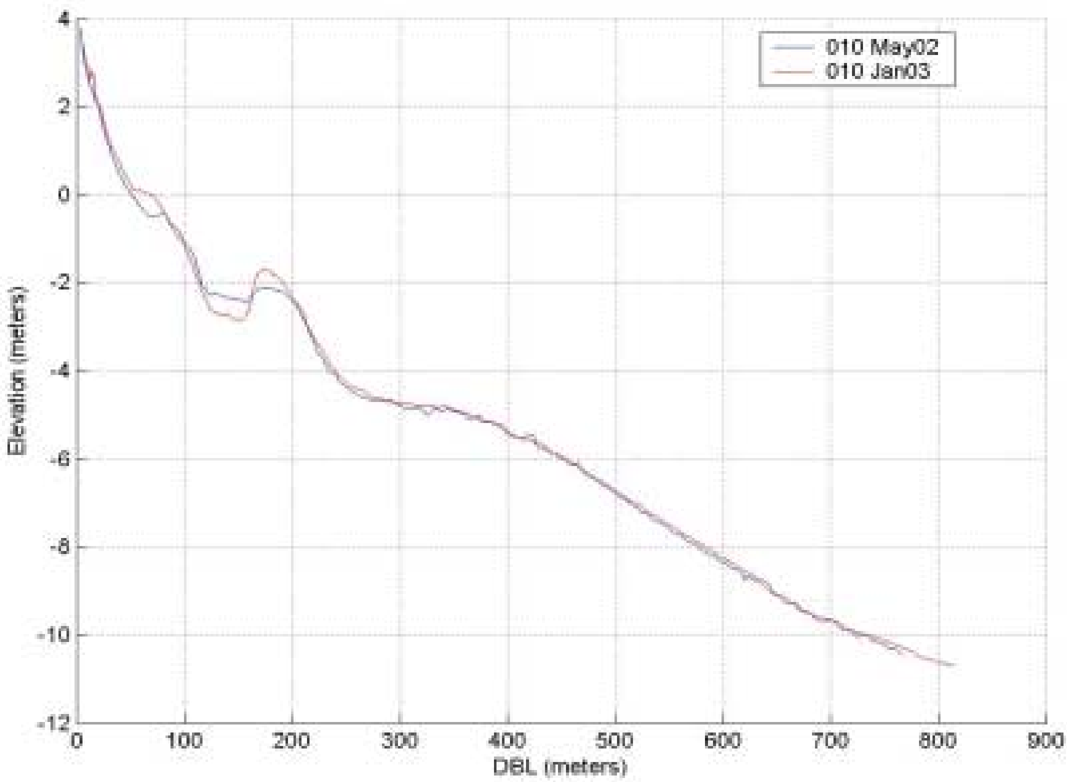
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DBL (meters)
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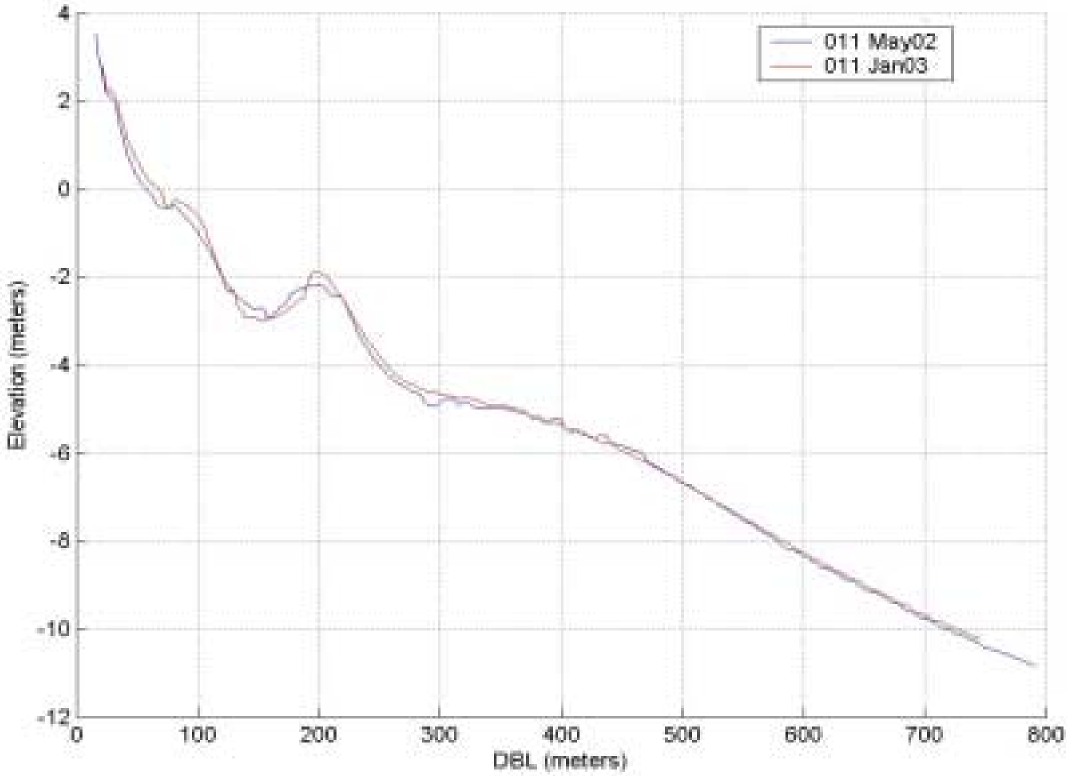

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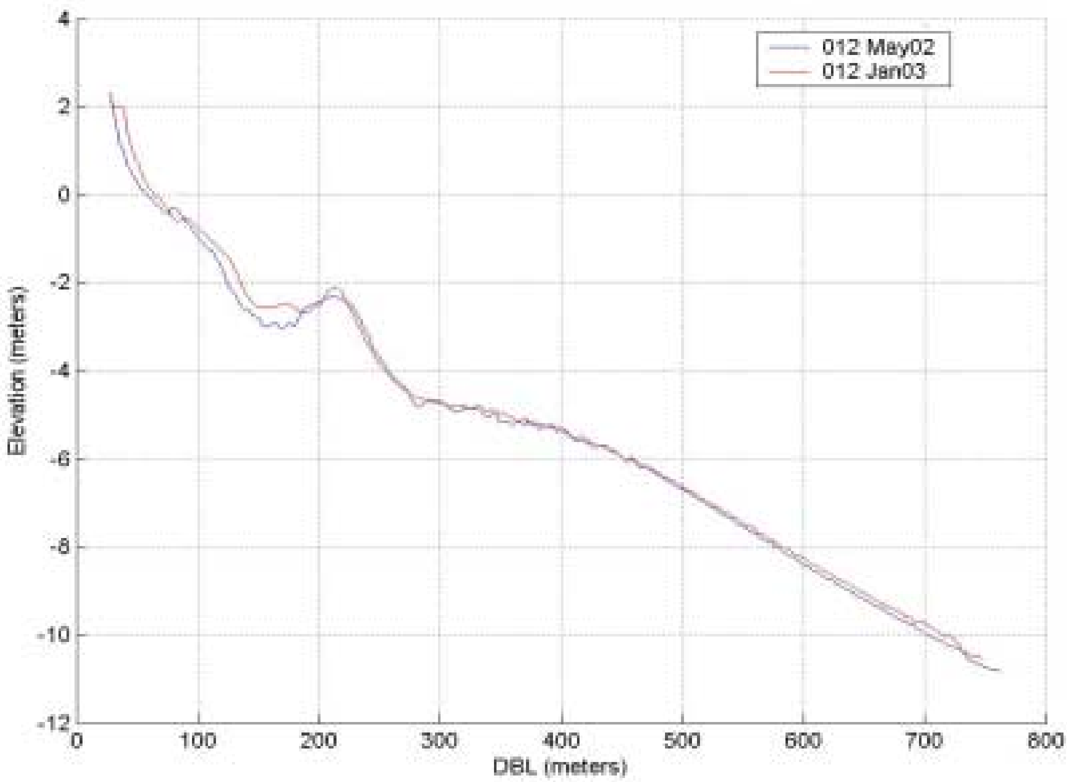
Elevation (meters)
DBL (meters)



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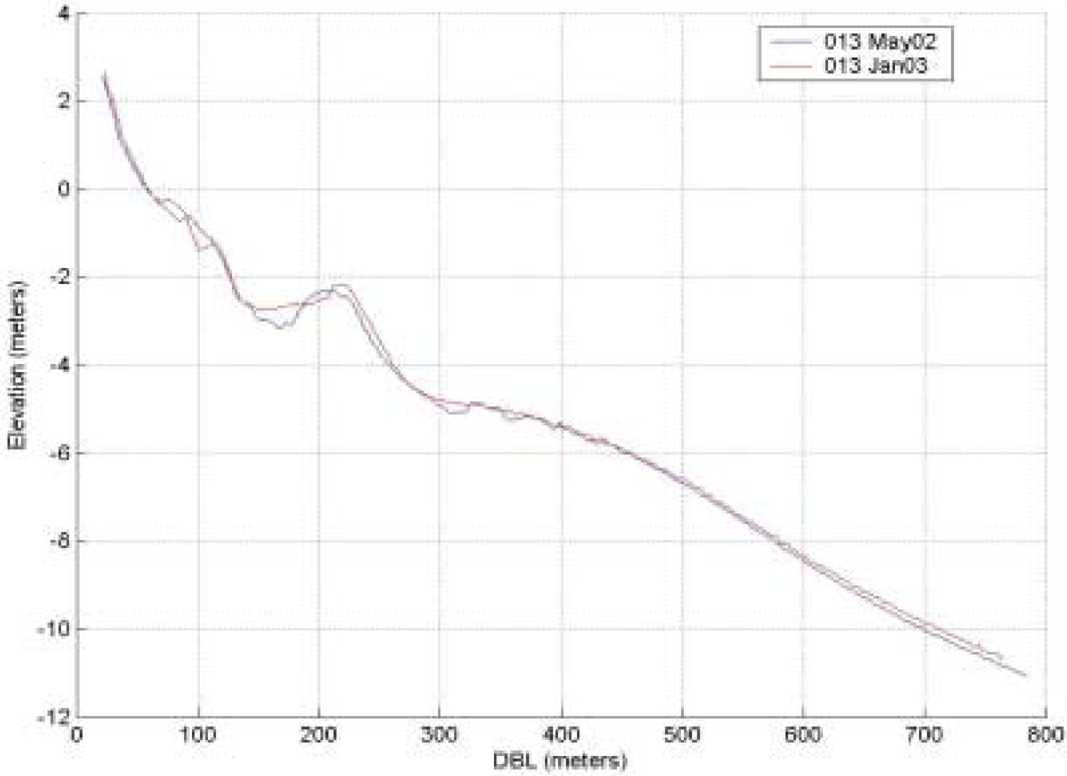
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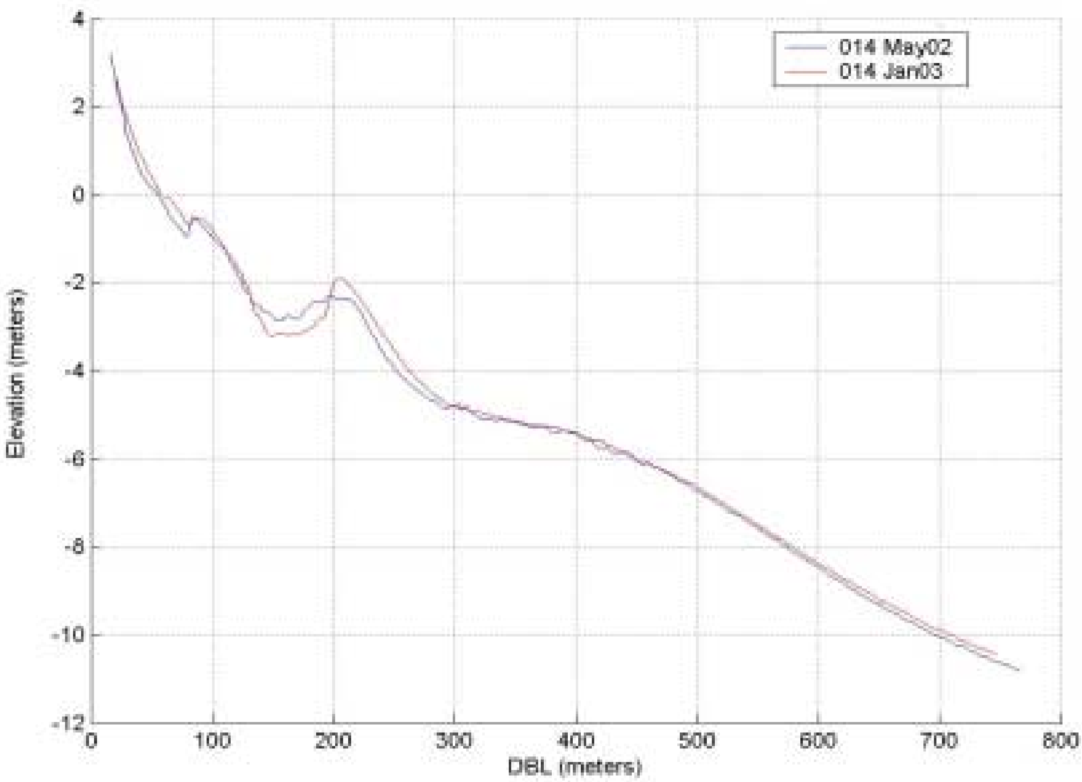
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DBL (meters)
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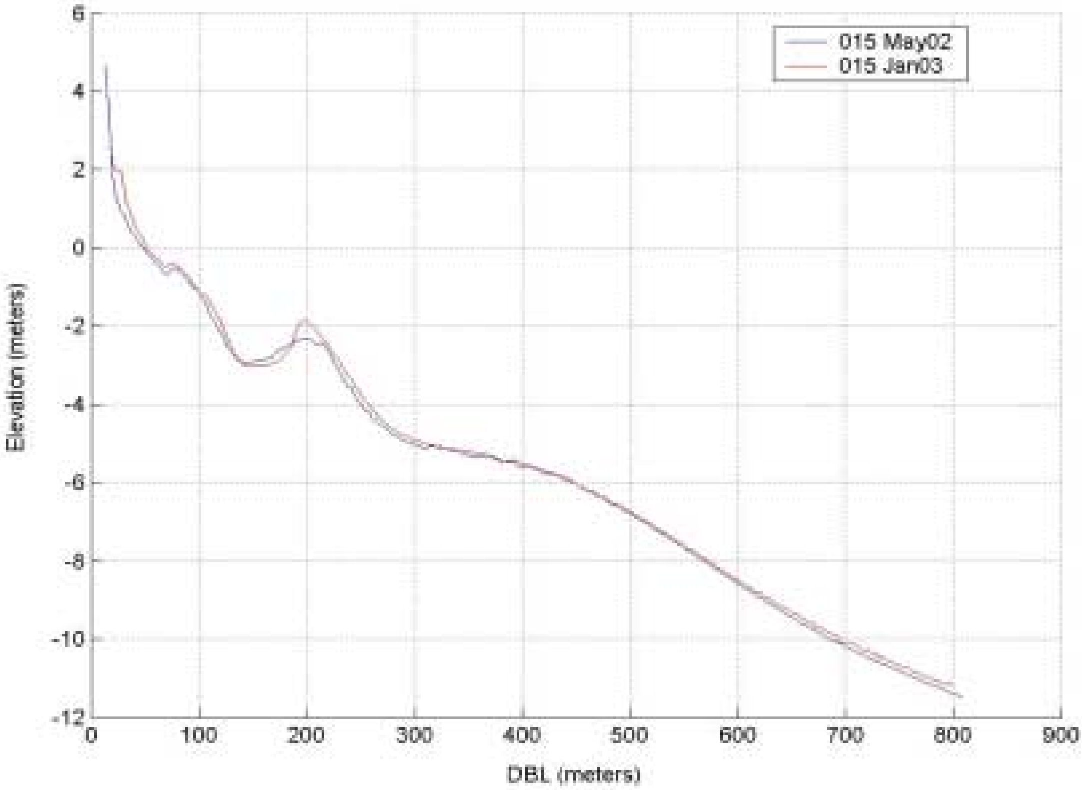

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015 Jan03
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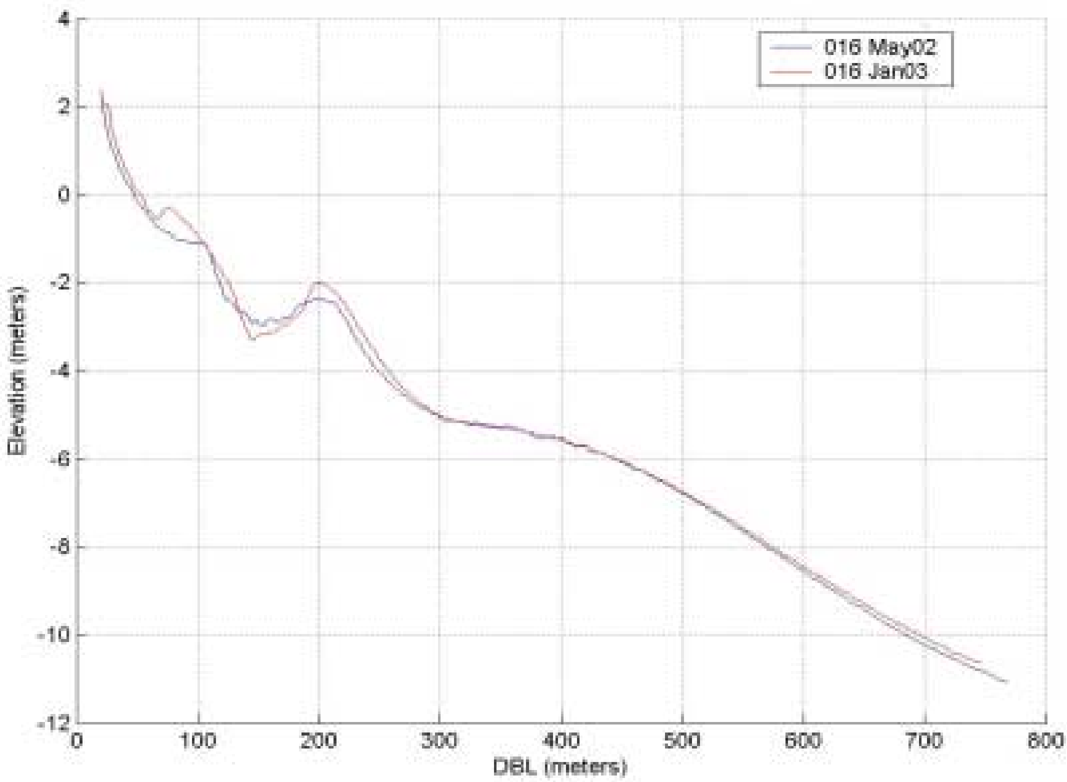
DBL (meters)



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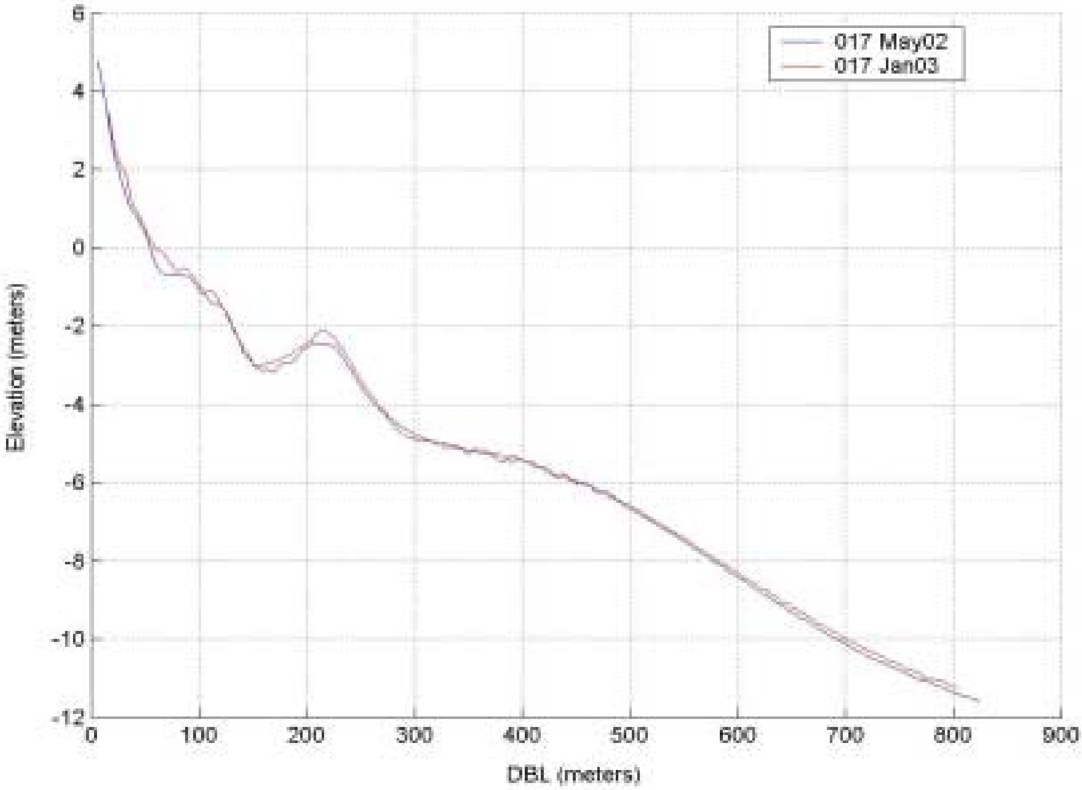
016 Jan03
Elevation (meters)
DBL (meters)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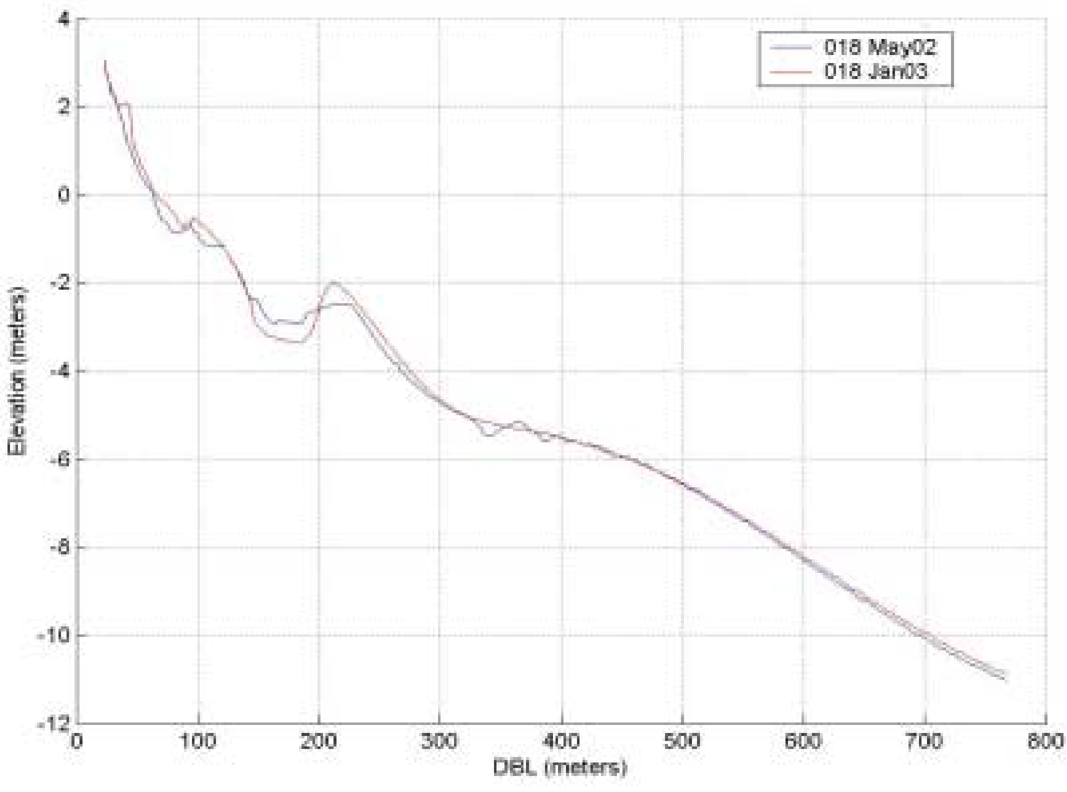
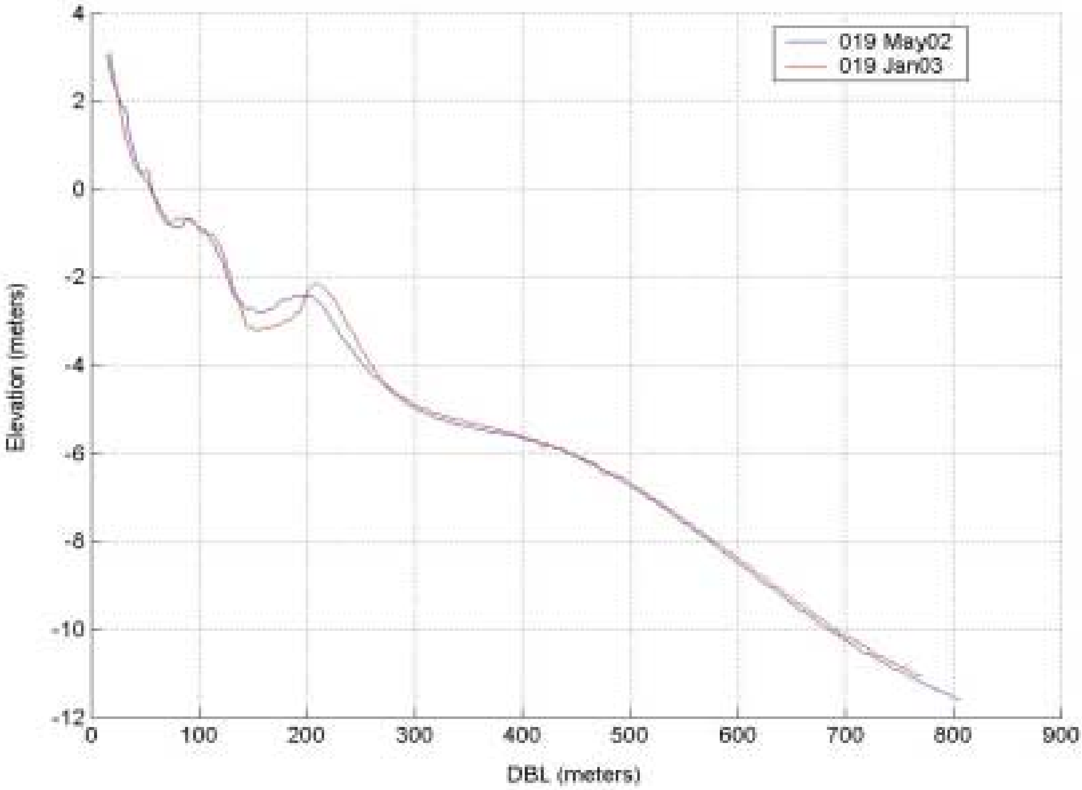
017 Jan03
Elevation (meters)
DBL (meters)


018 May02
018 Jan03
Elevation (meters)
DBL (meters)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019 Jan03
Elevation (meters)
DBL (meters)
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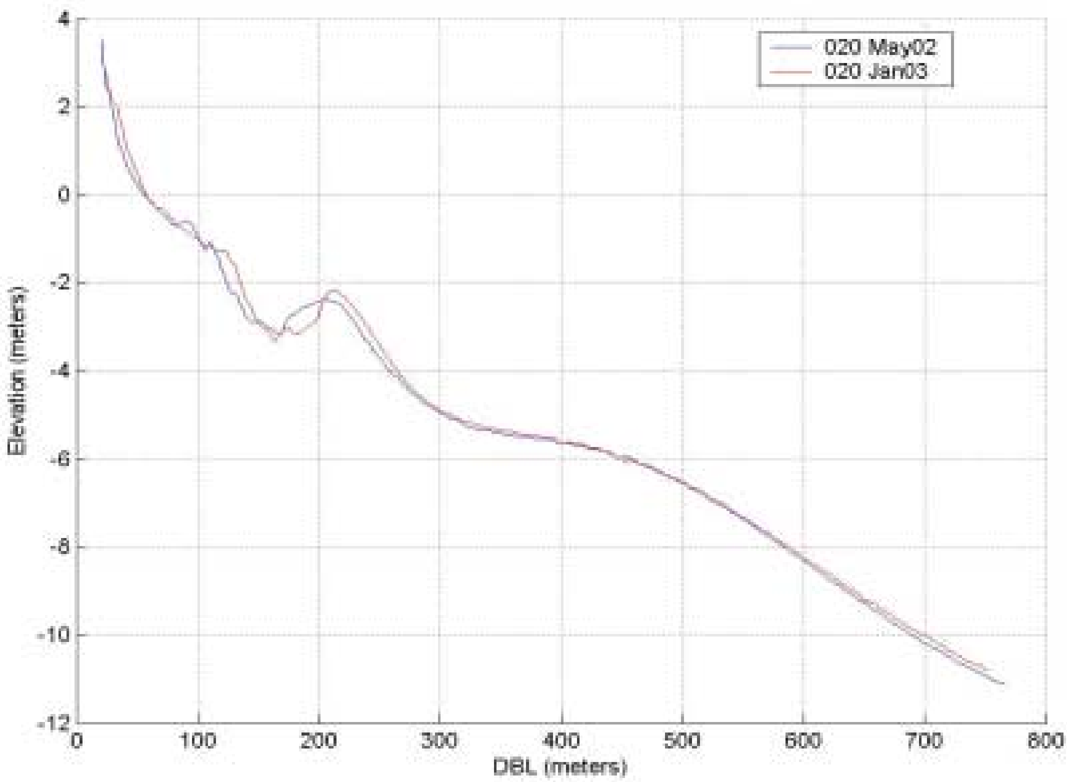
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Elevation (meters)
DBL (meters)
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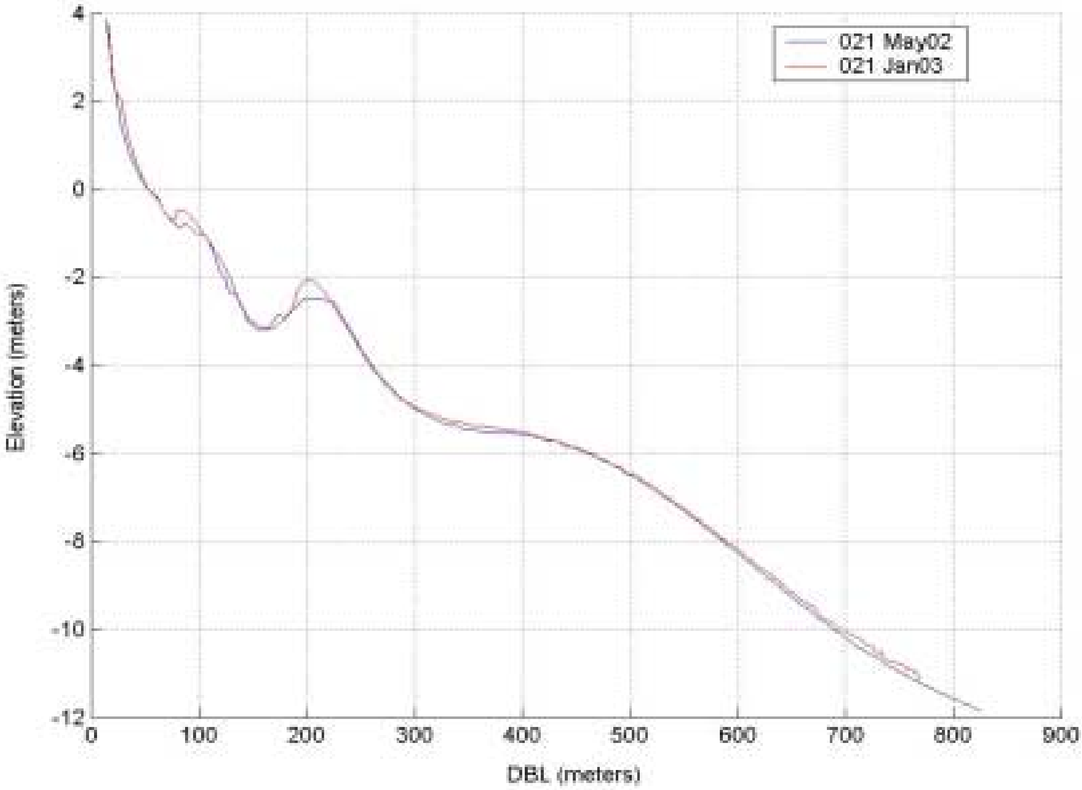
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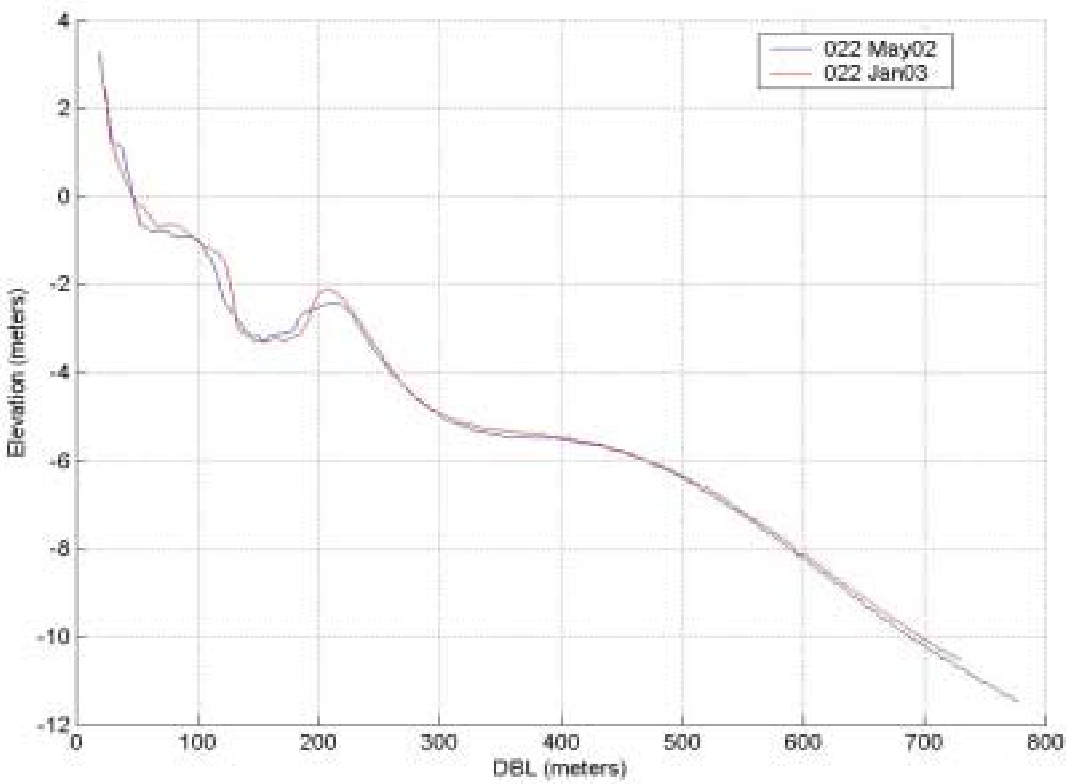
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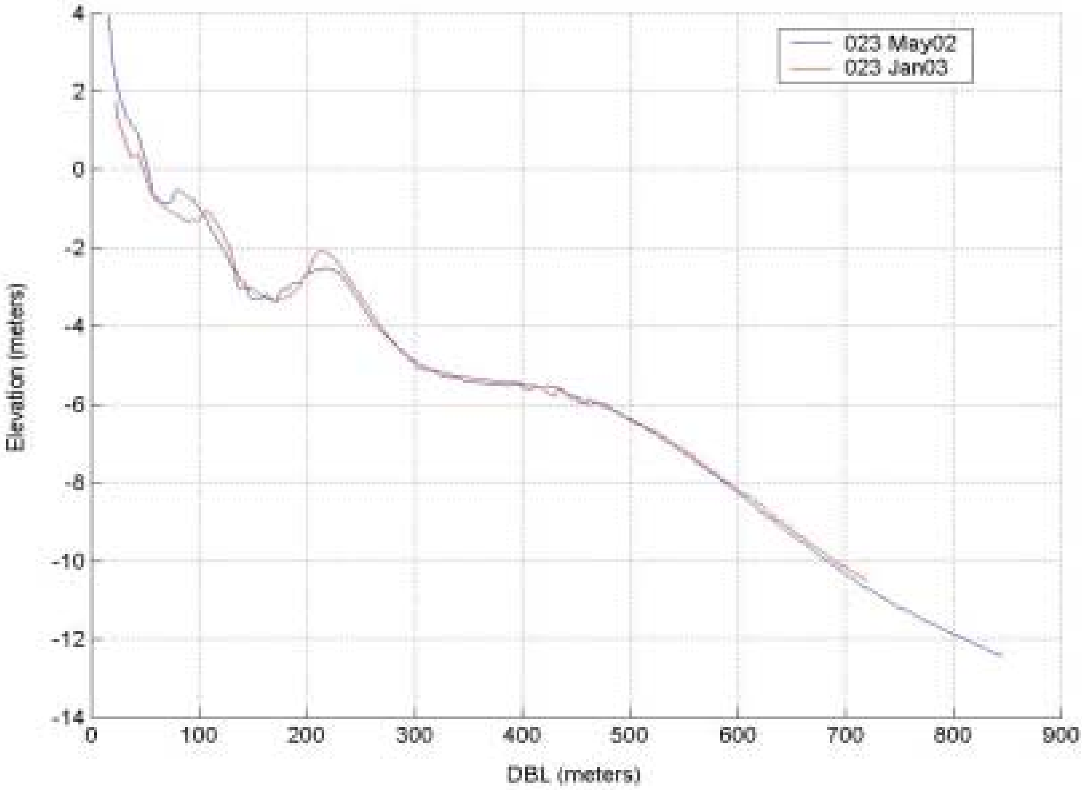
Elevation (meters)
DBL (meters)



023 May02
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Elevation (meters)
DBL (meters)
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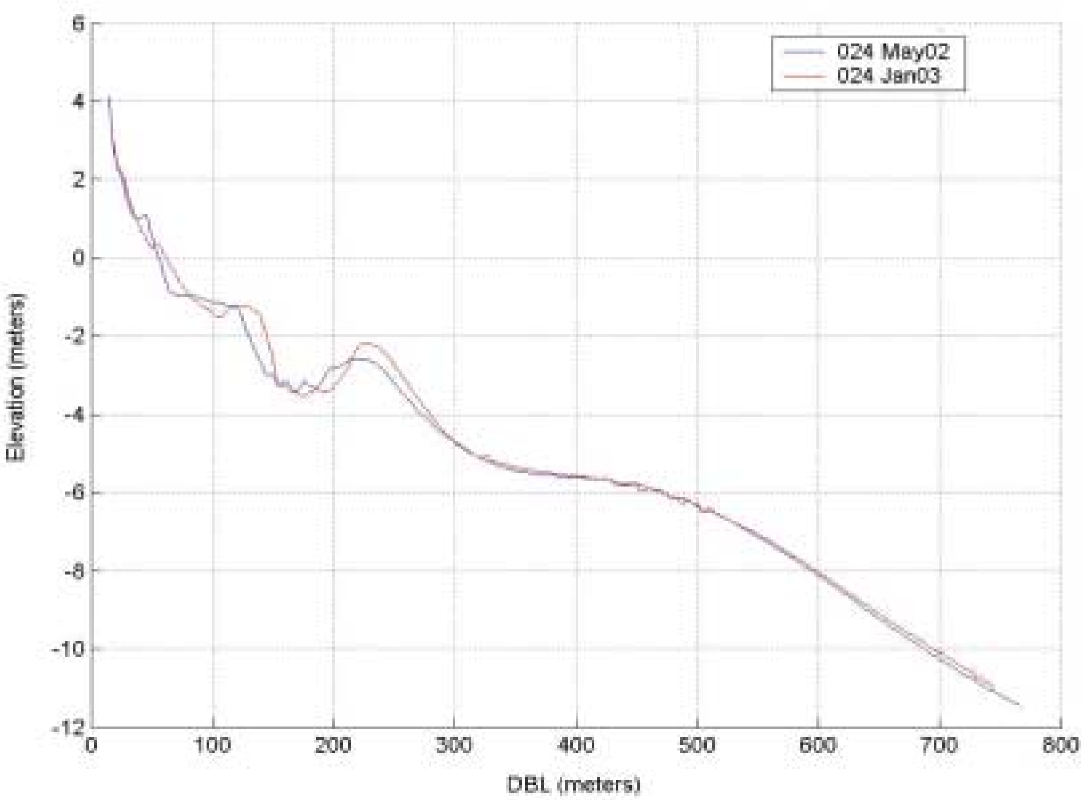

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Elevation (meters)
DBL (meters)
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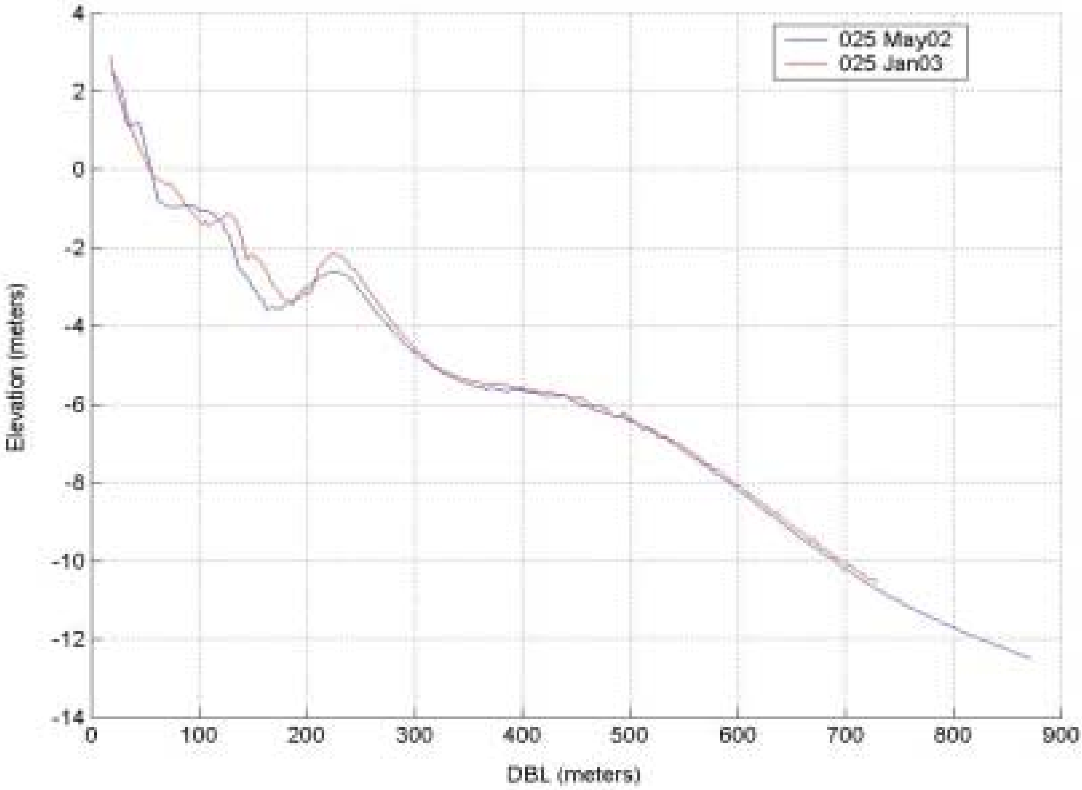
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Elevation (meters)
DBL (meters)
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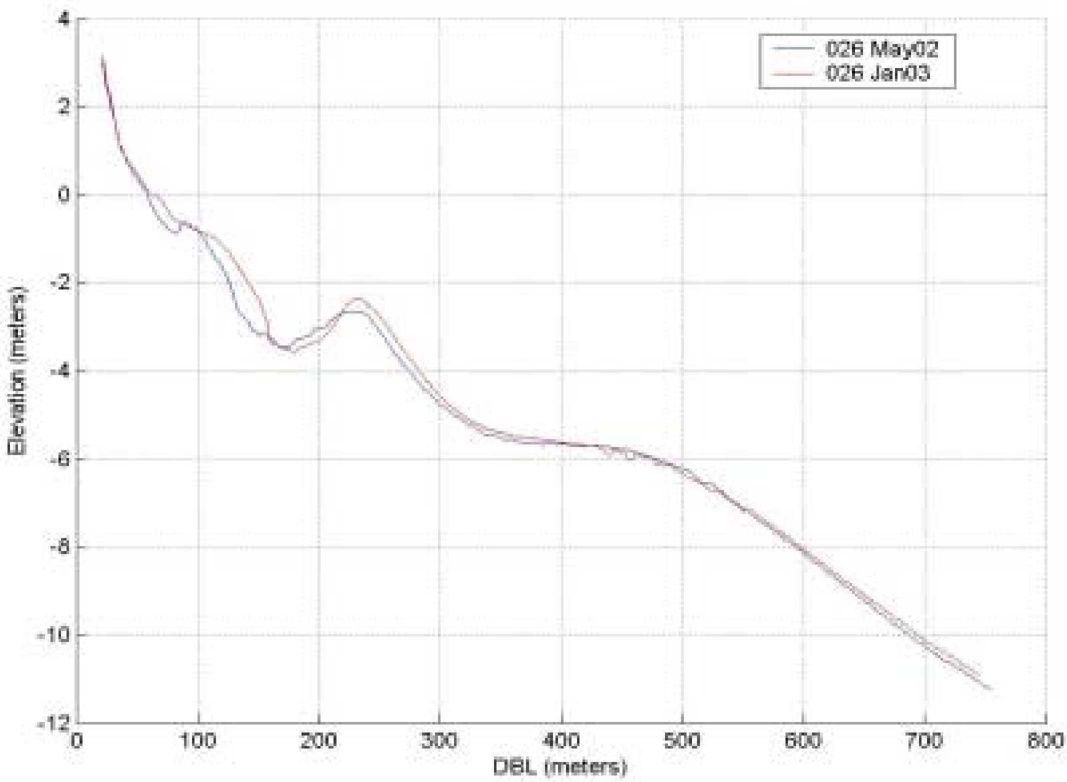
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Elevation (meters)
DBL (meters)
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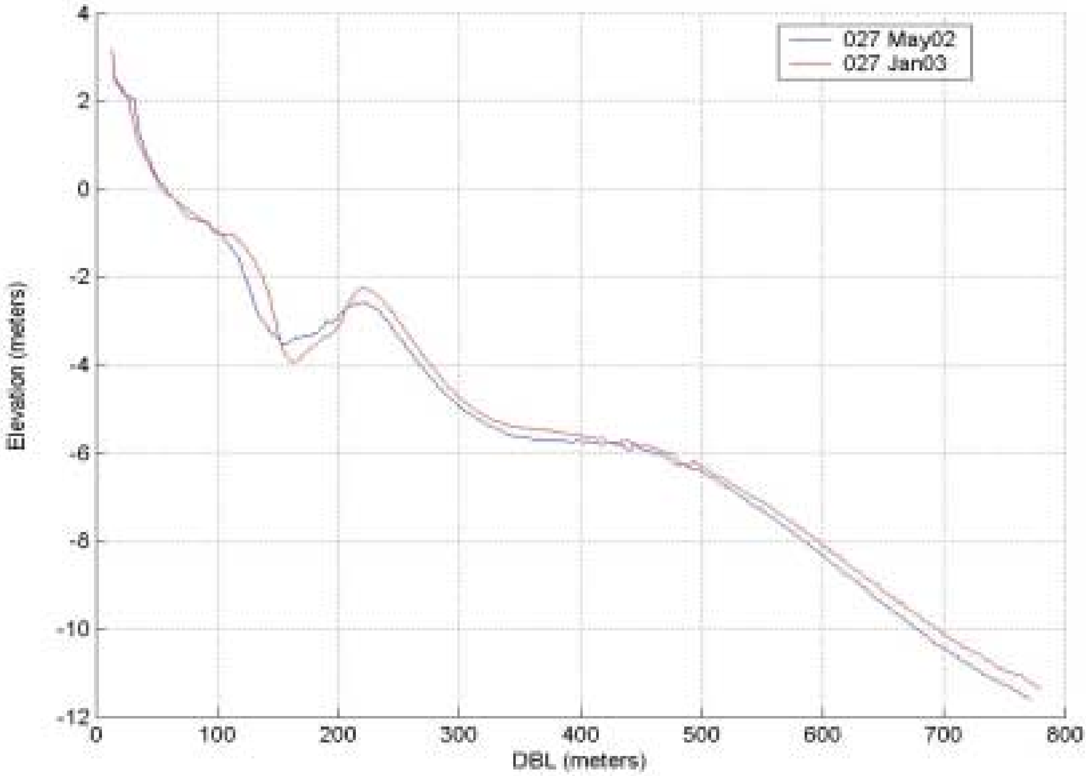
027 May02
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Elevation (meters)
DBL (meters)
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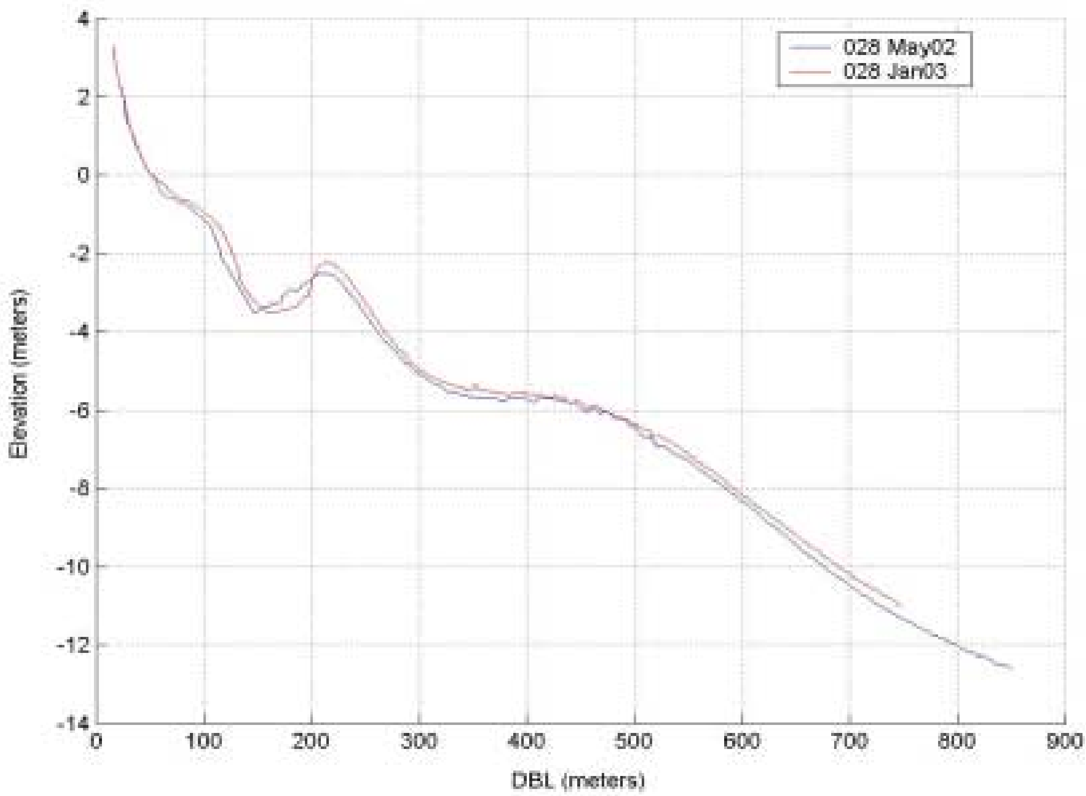
028 May02
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Elevation (meters)
DBL (meters)
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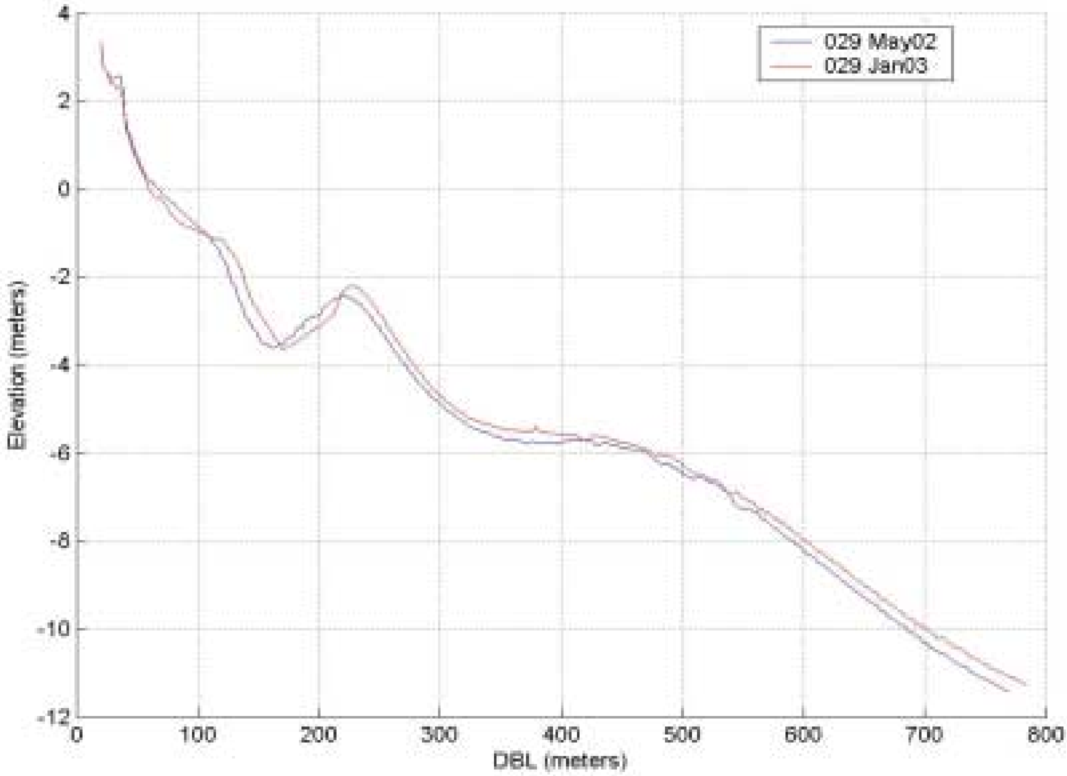

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Elevation (meters)
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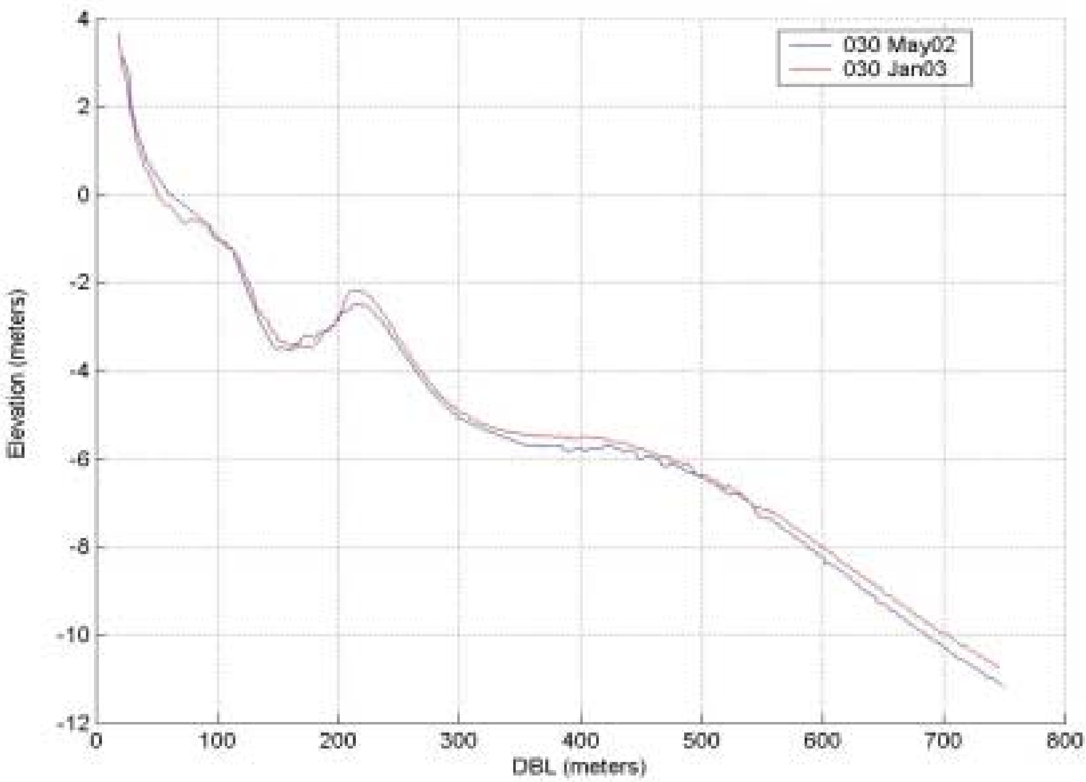

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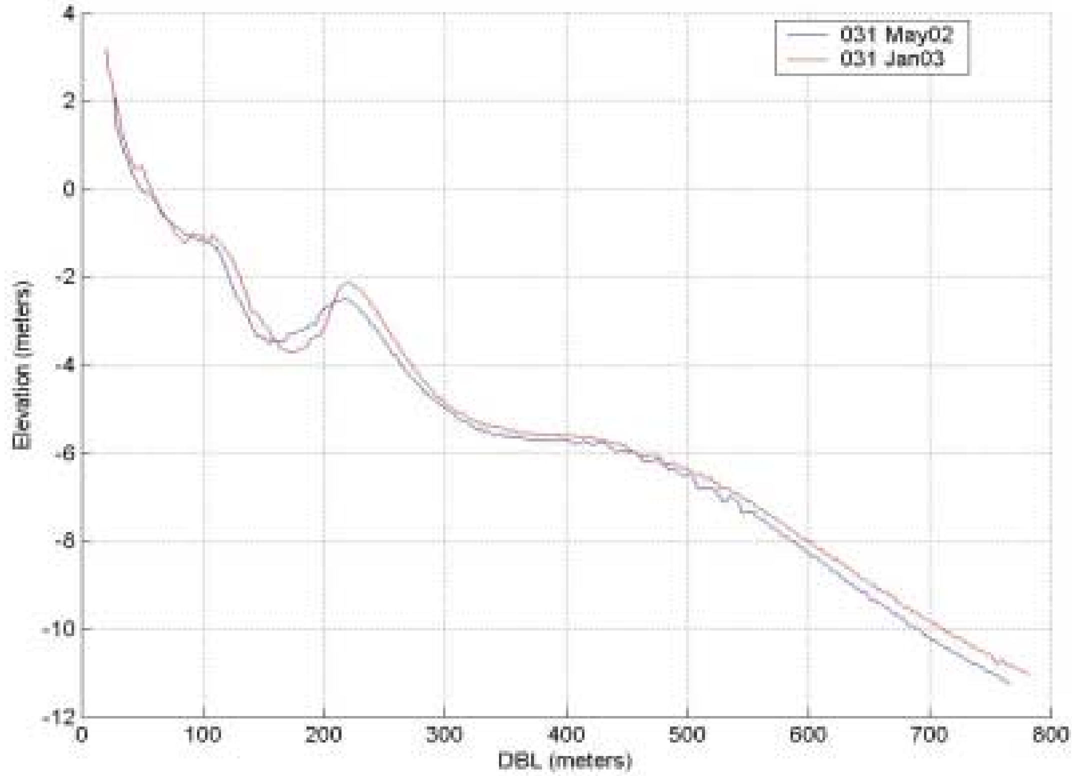
Elevation (meters)
DBL (meters)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Elevation (meters)
DBL (meters)
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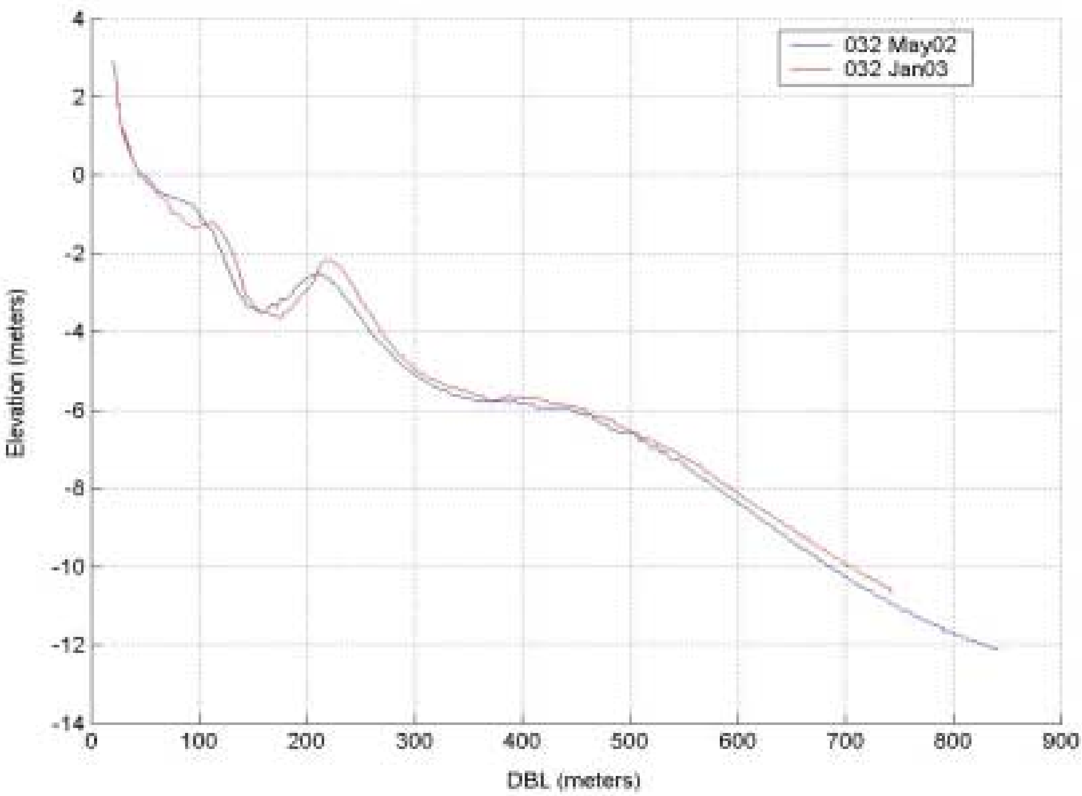
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Elevation (meters)
DBL (meters)
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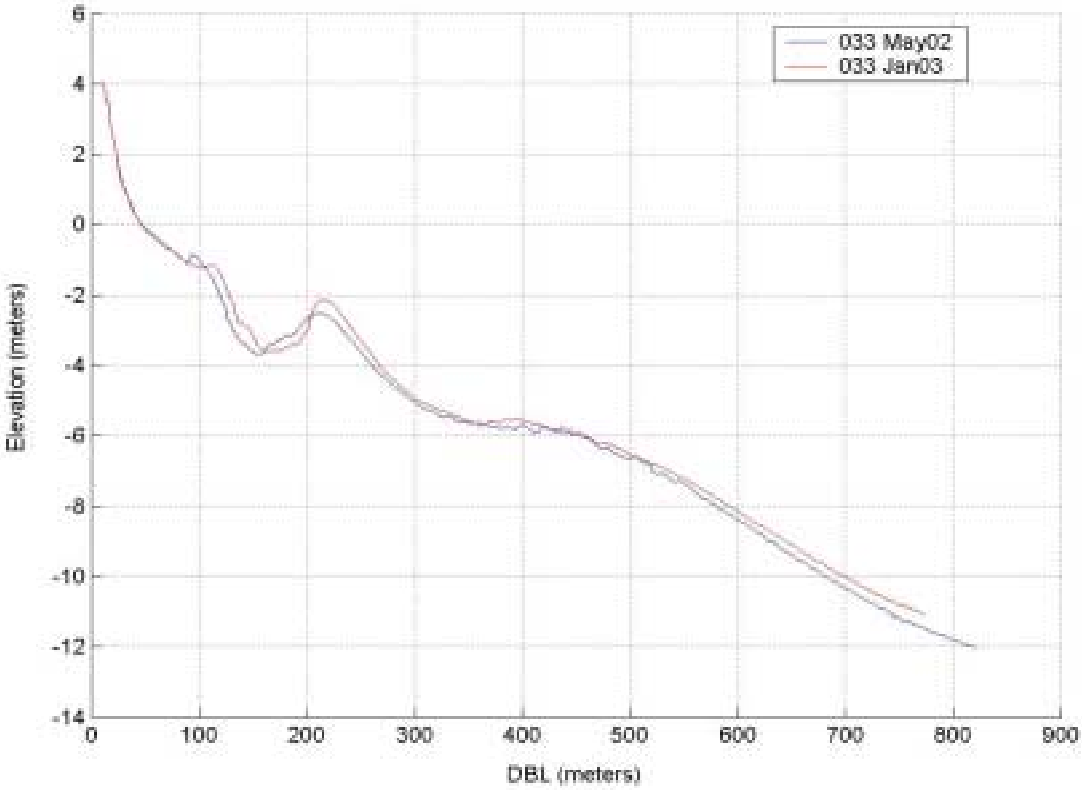
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DBL (meters)
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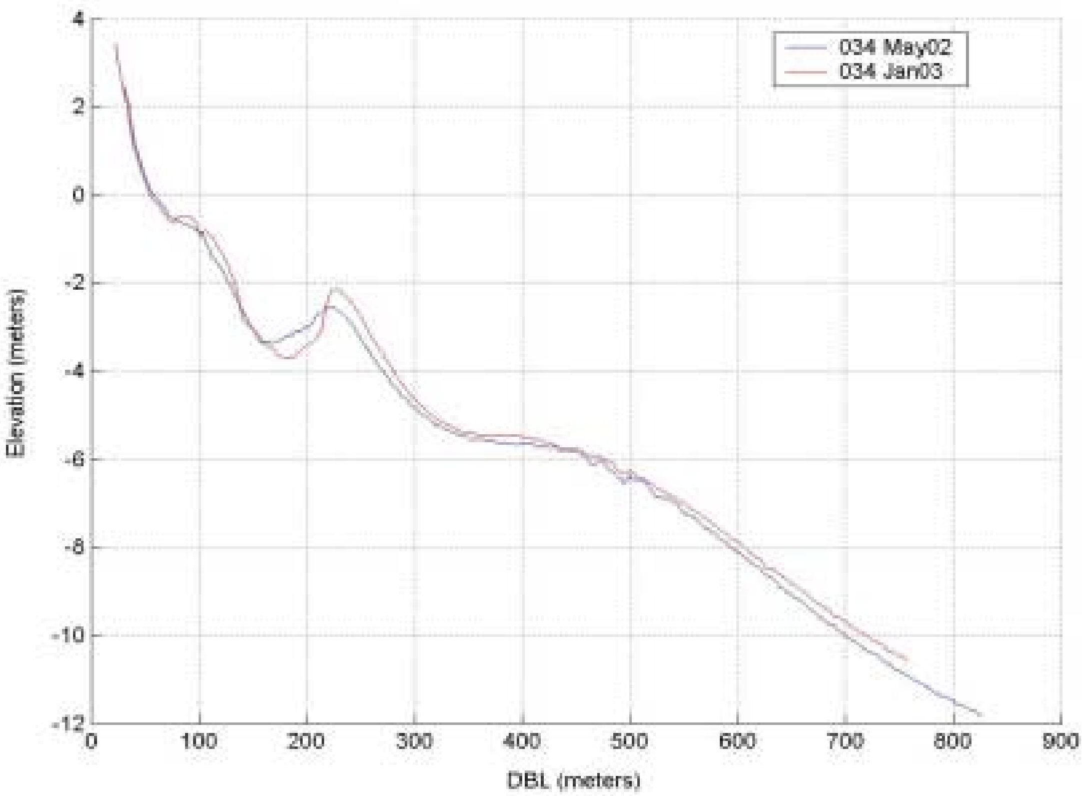
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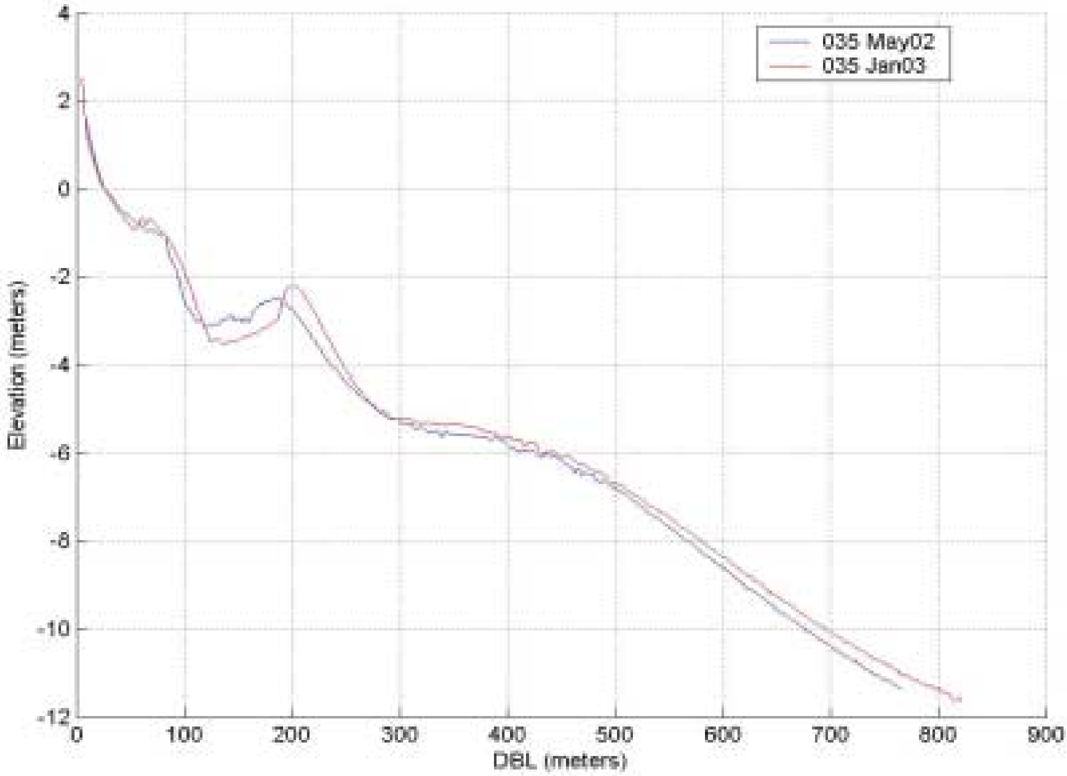
035 May02
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Elevation (meters)
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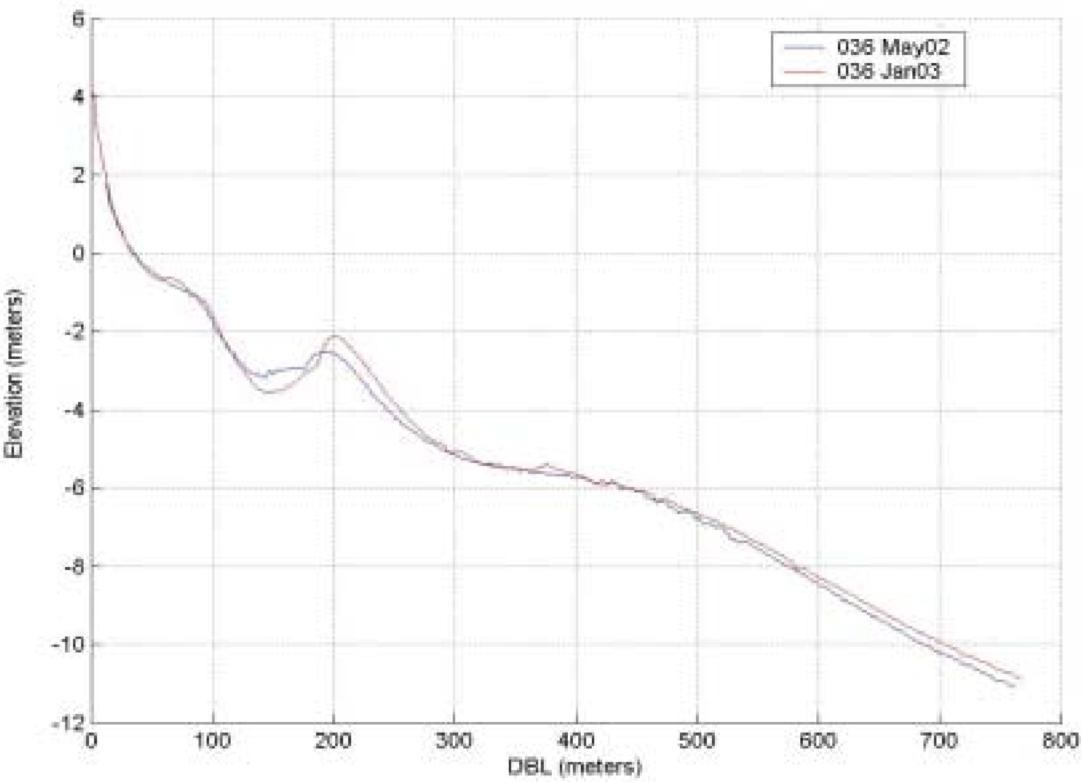
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Elevation (meters)
DBL (meters)
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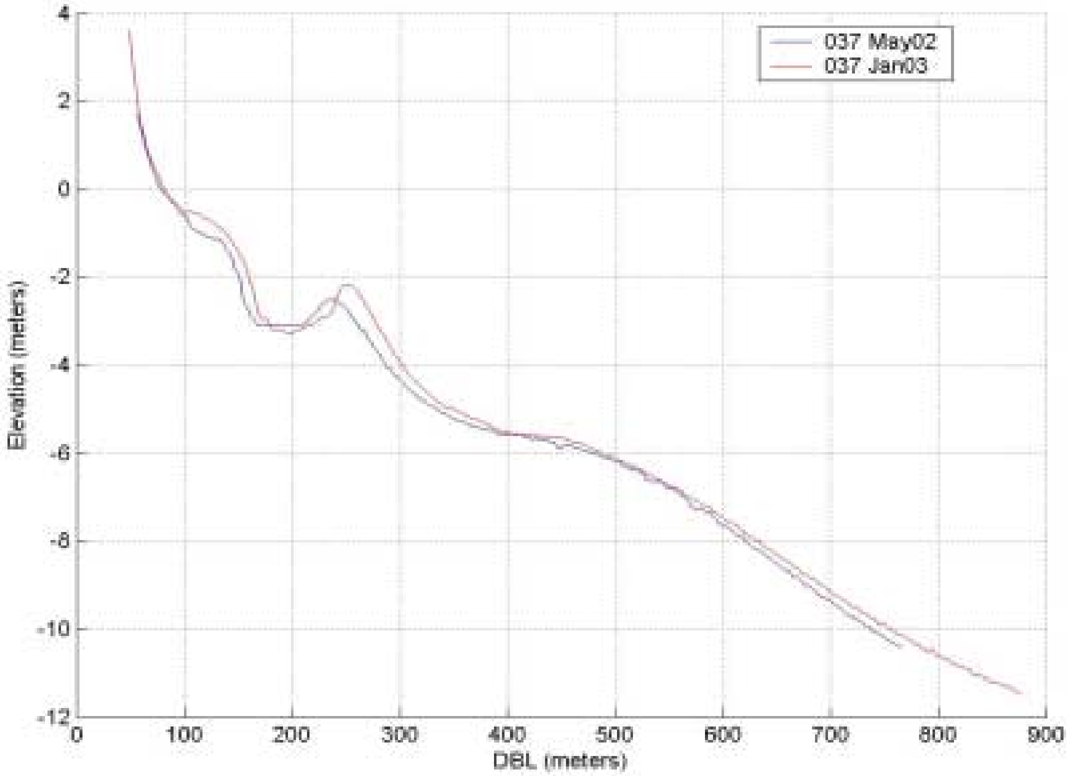
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Elevation (meters)
DBL (meters)
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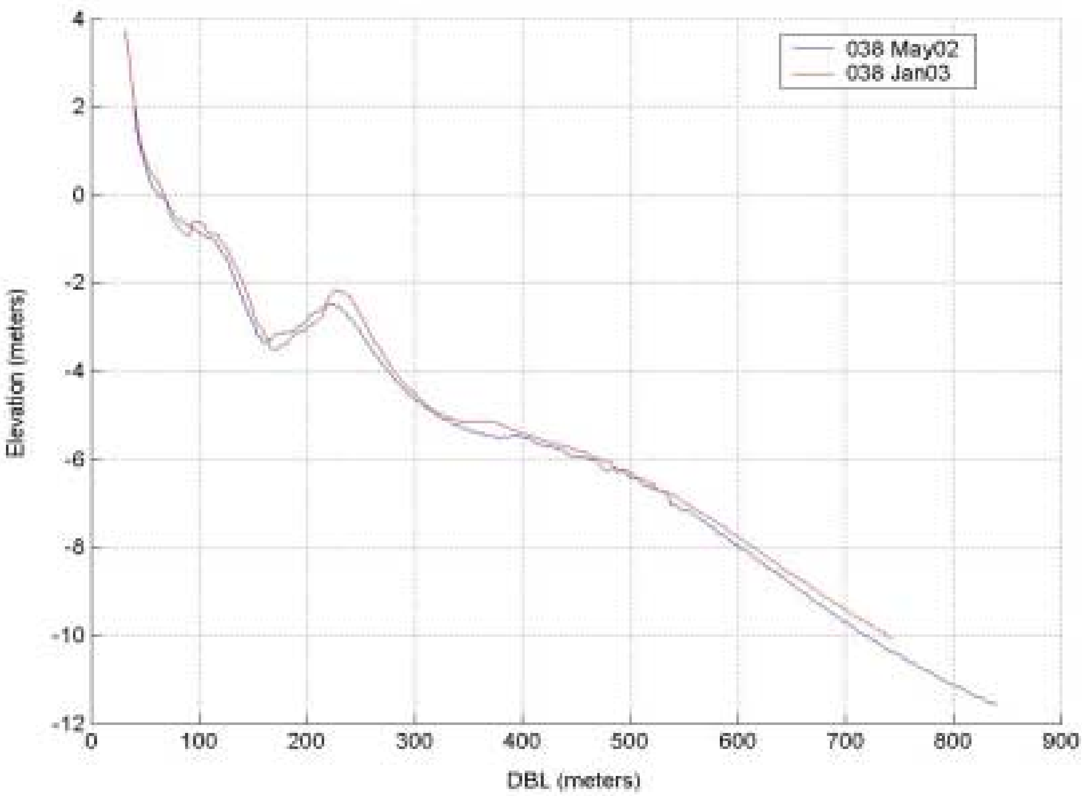
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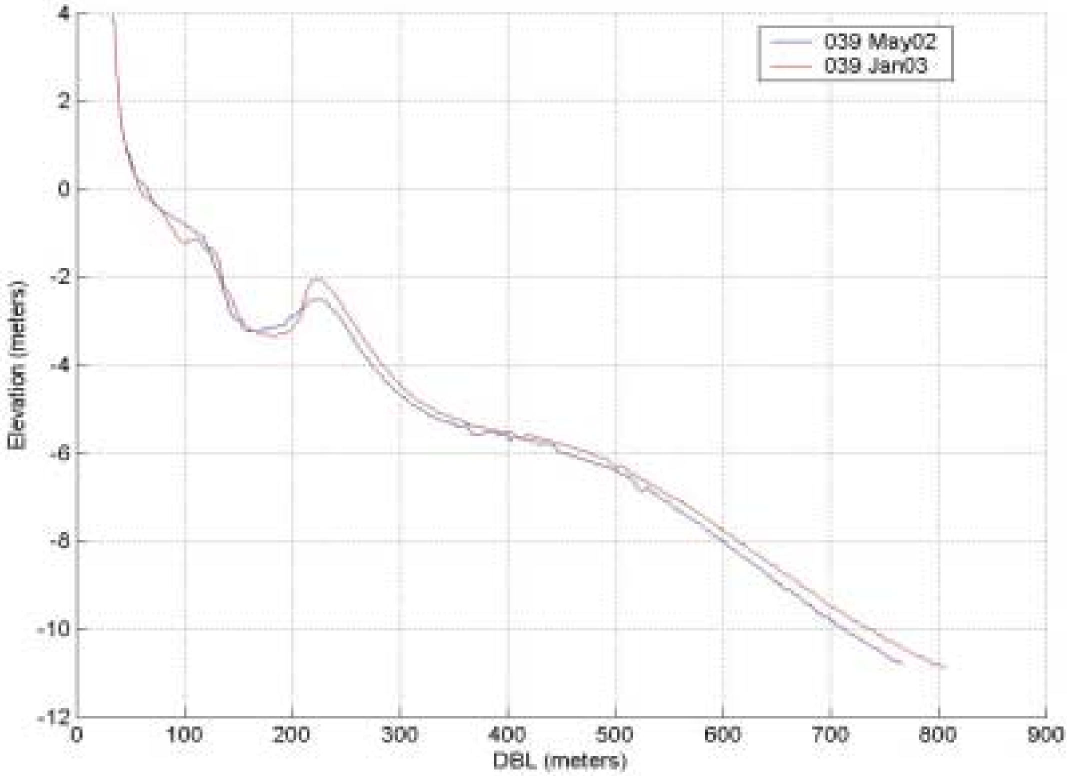
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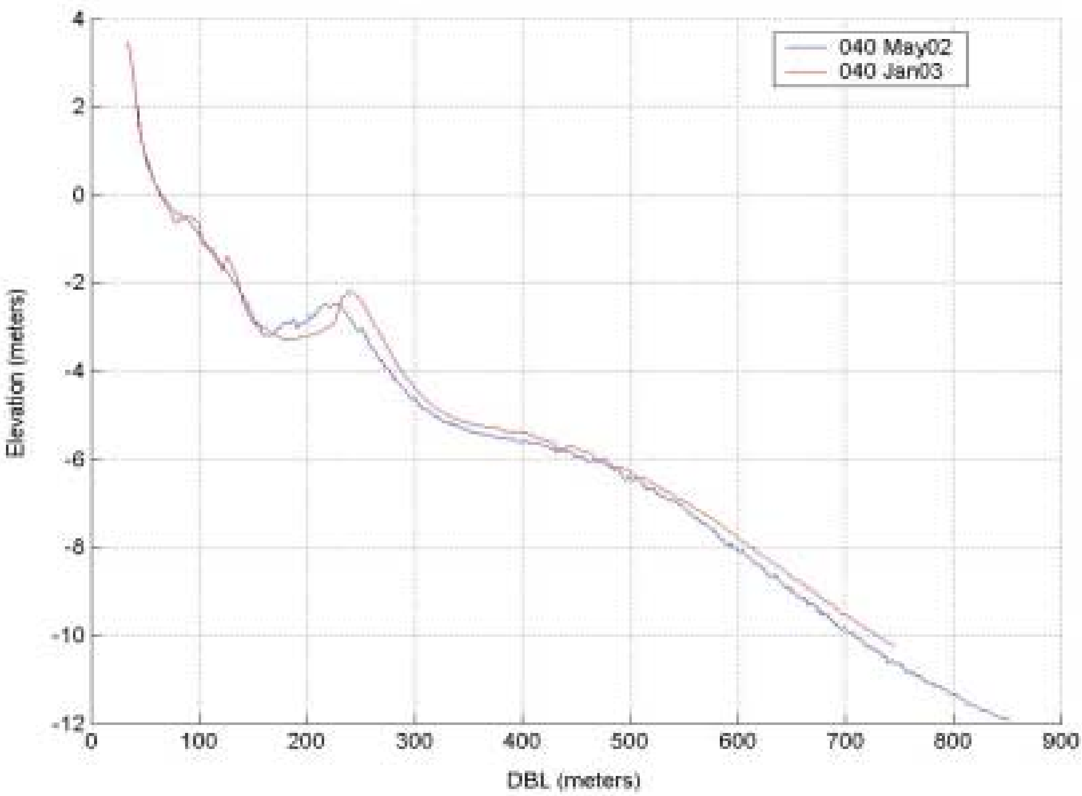
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DBL (meters)
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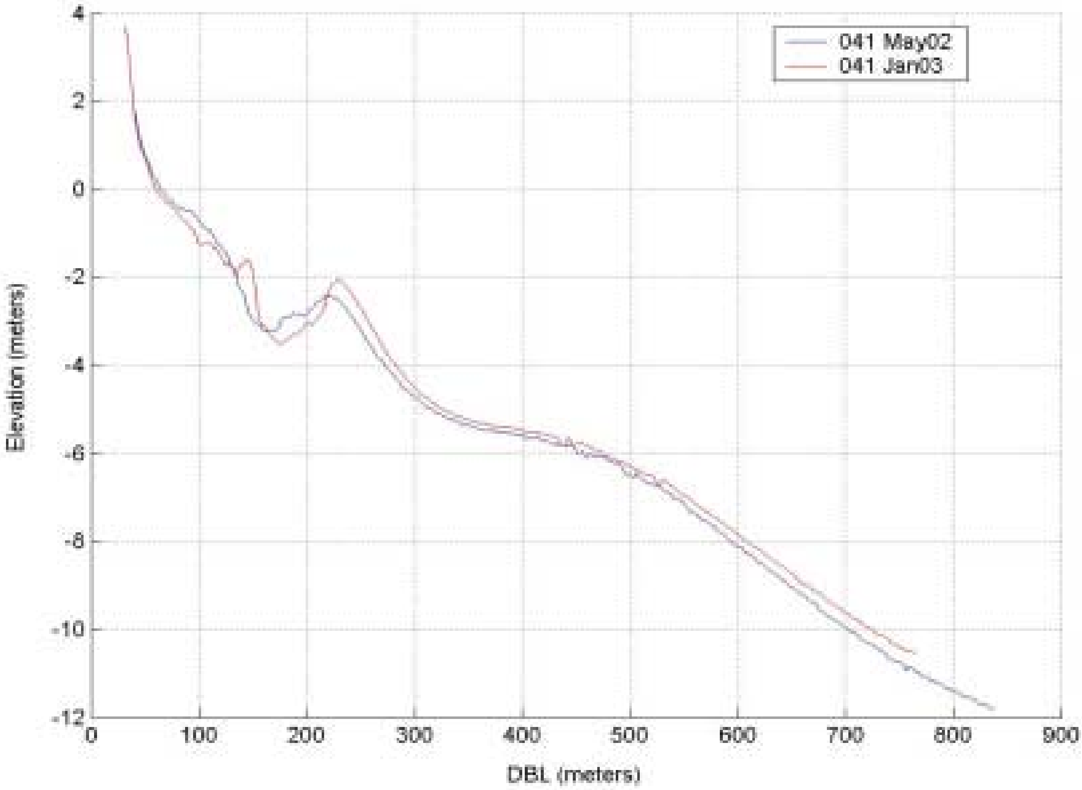
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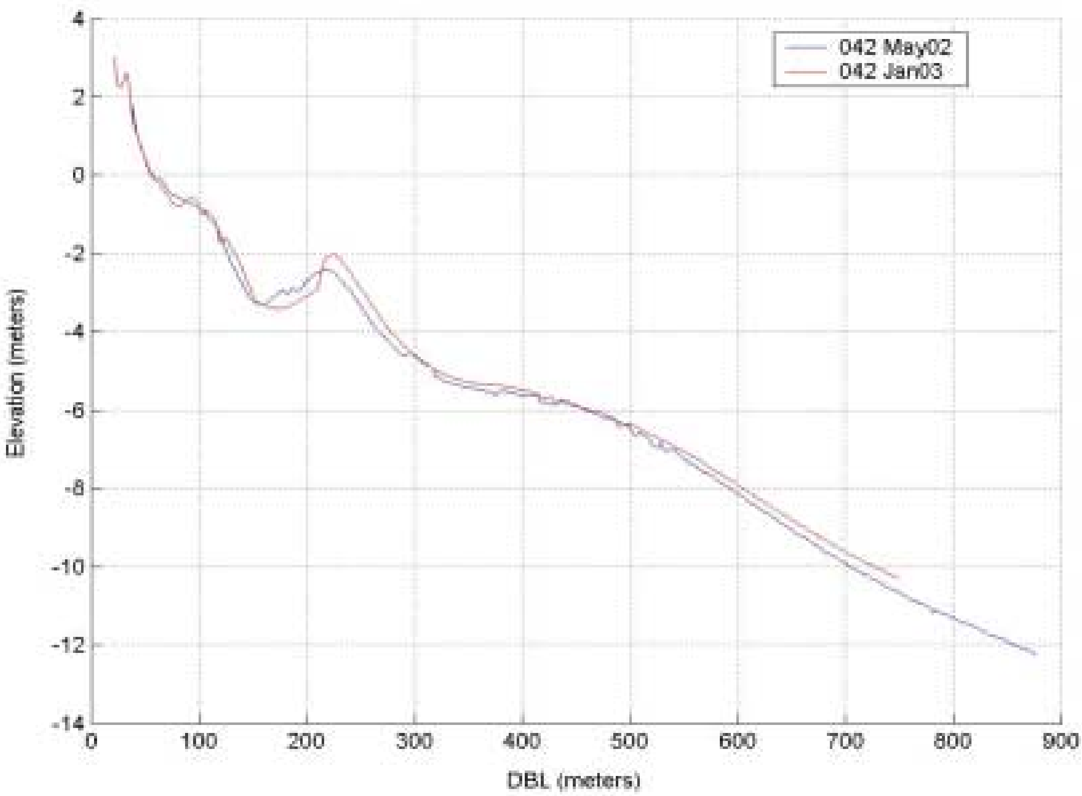
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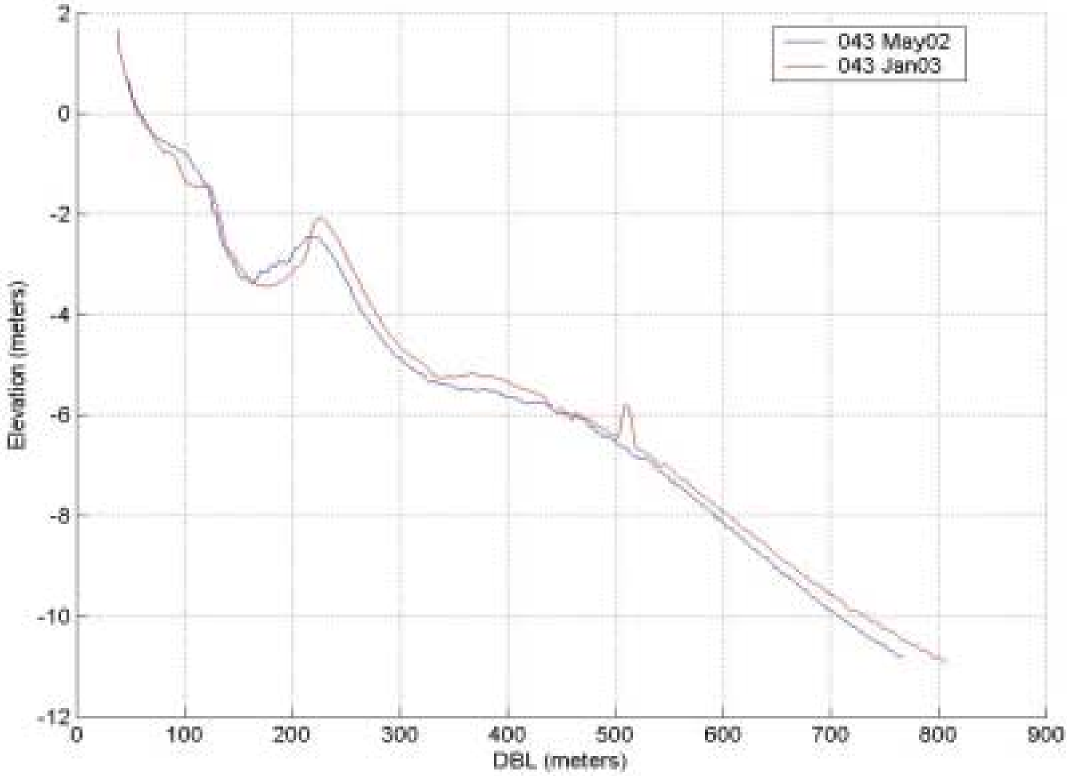
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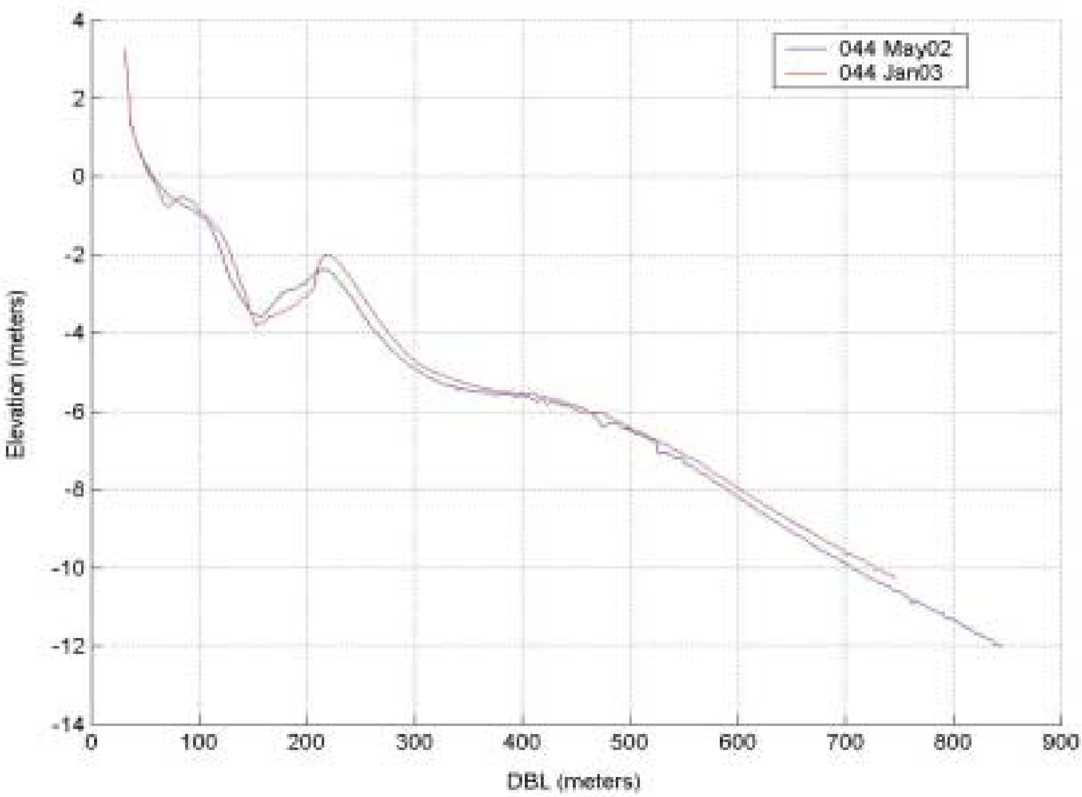
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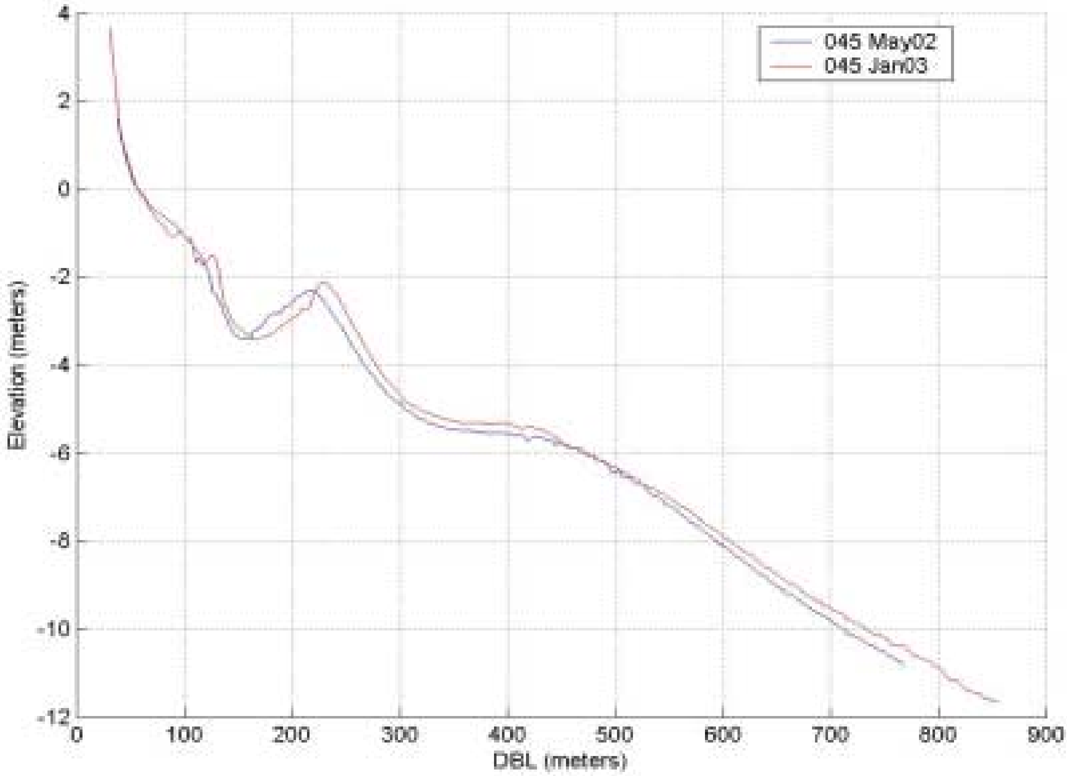

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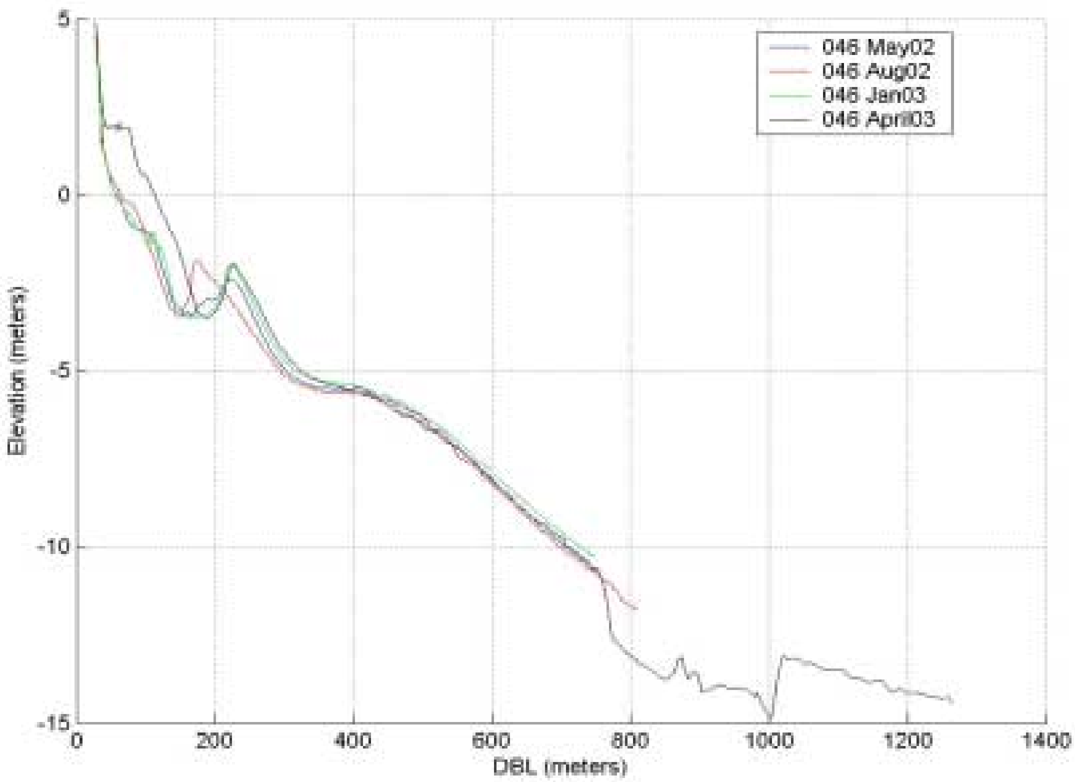
Elevation (meters)
DBL (meters)



046 May02
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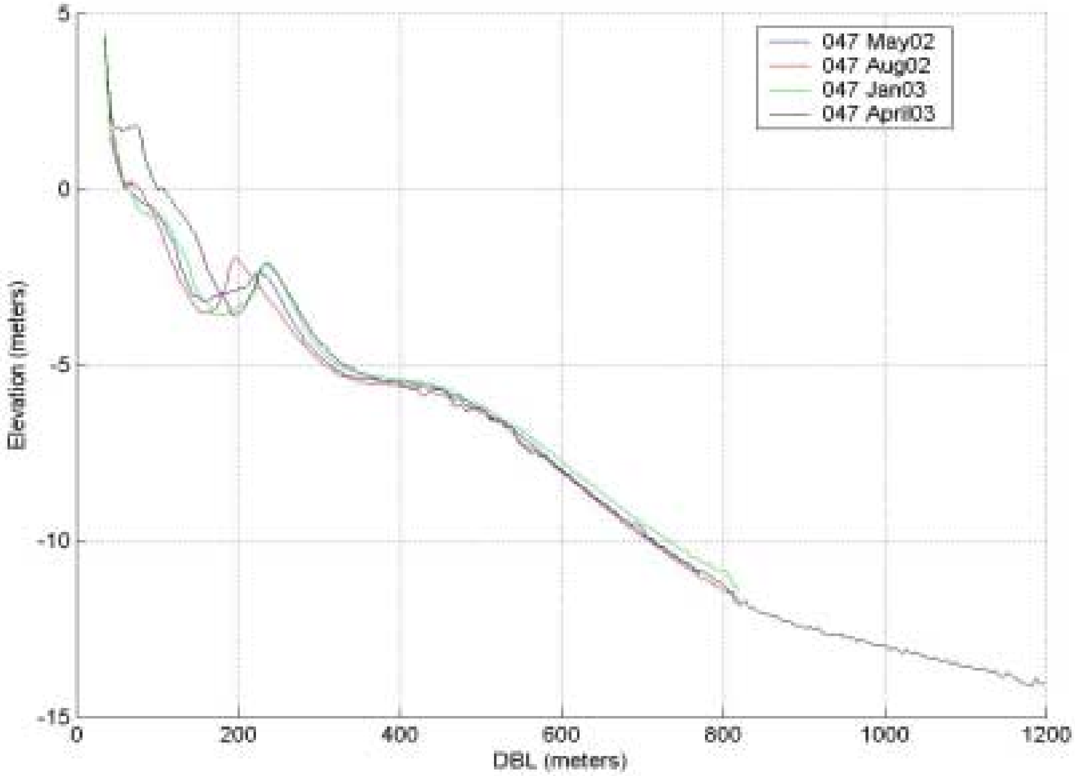
Elevation (meters)
DBL (meters)



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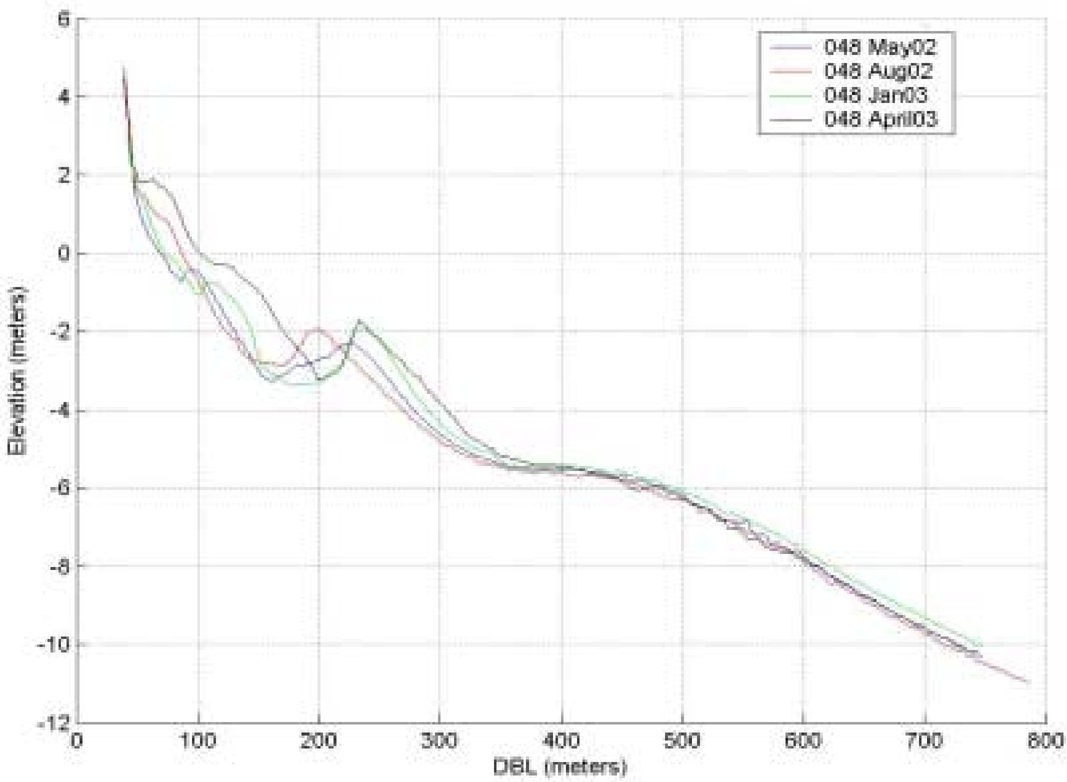

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Elevation (meters)
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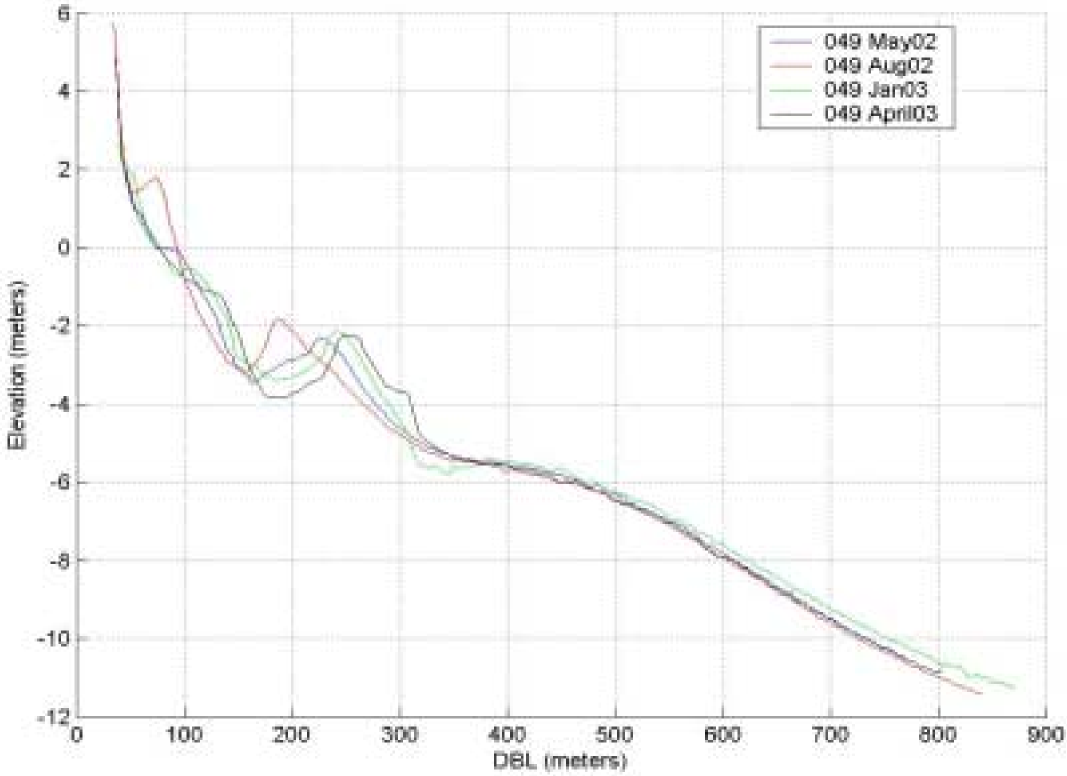
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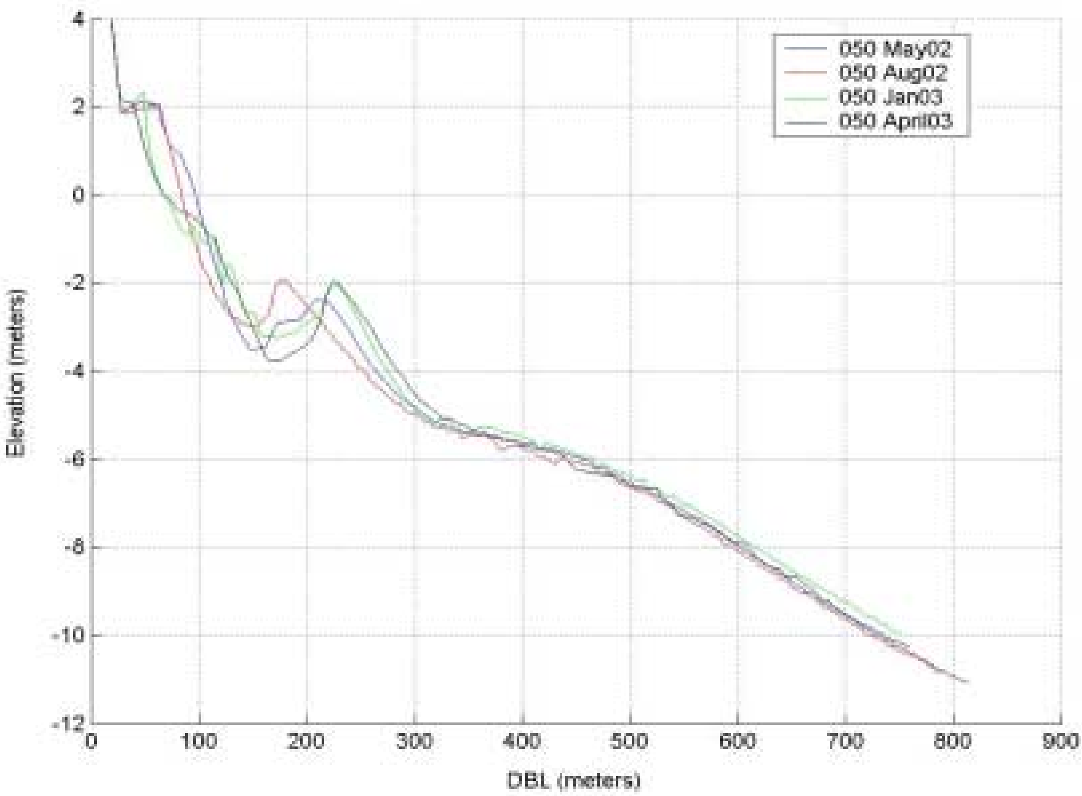
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Elevation (meters)
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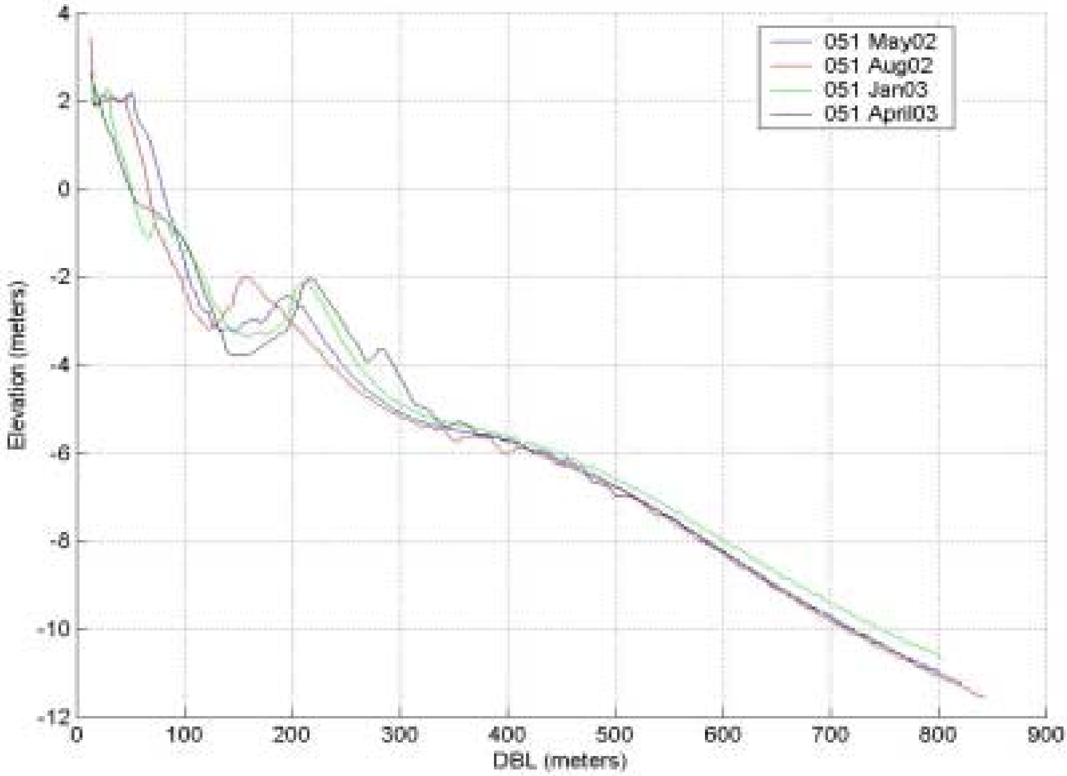
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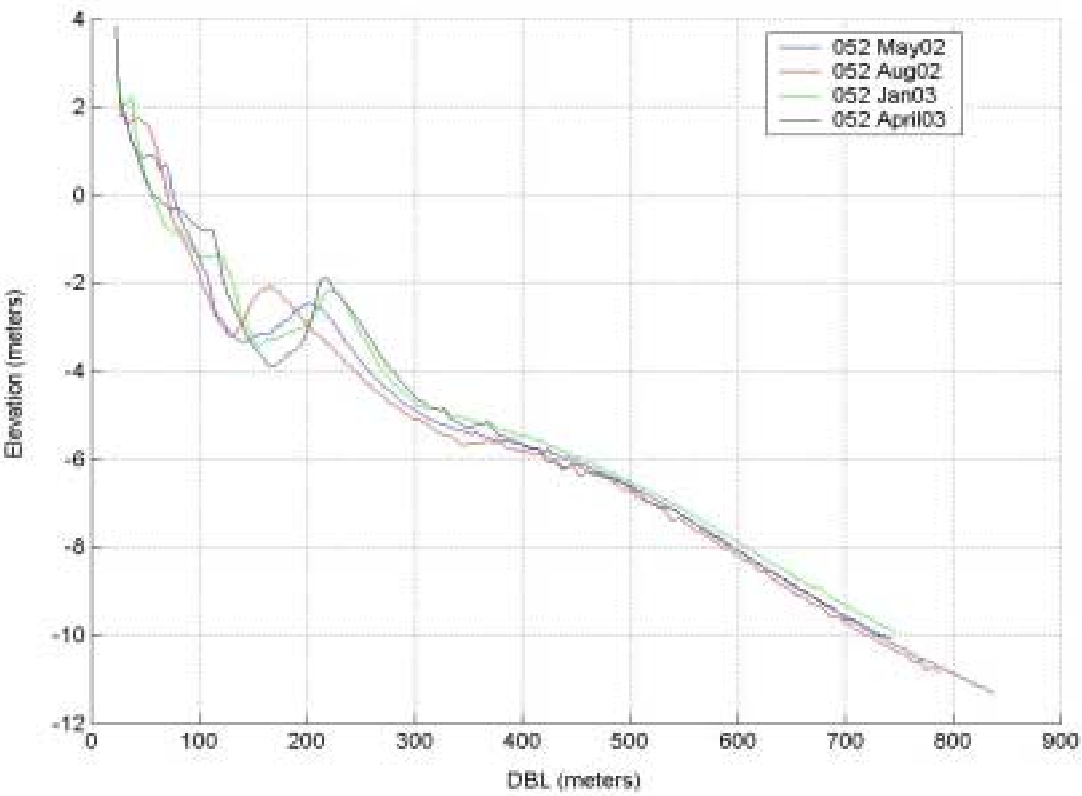
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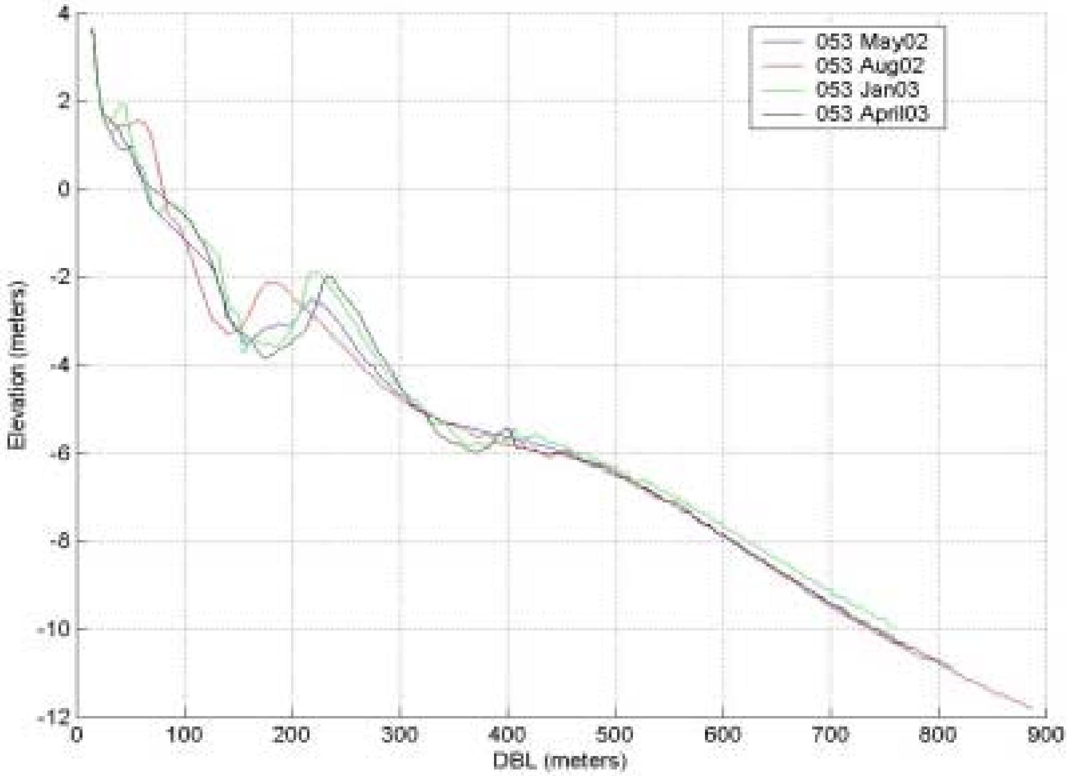
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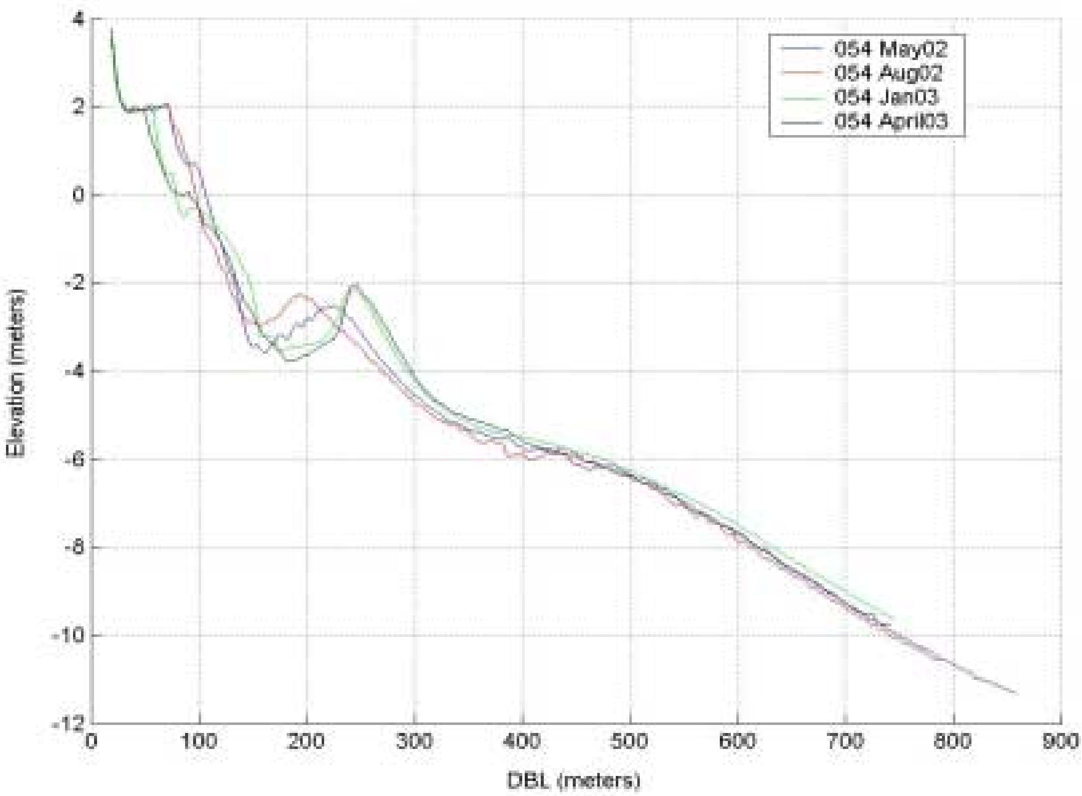
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Elevation (meters)
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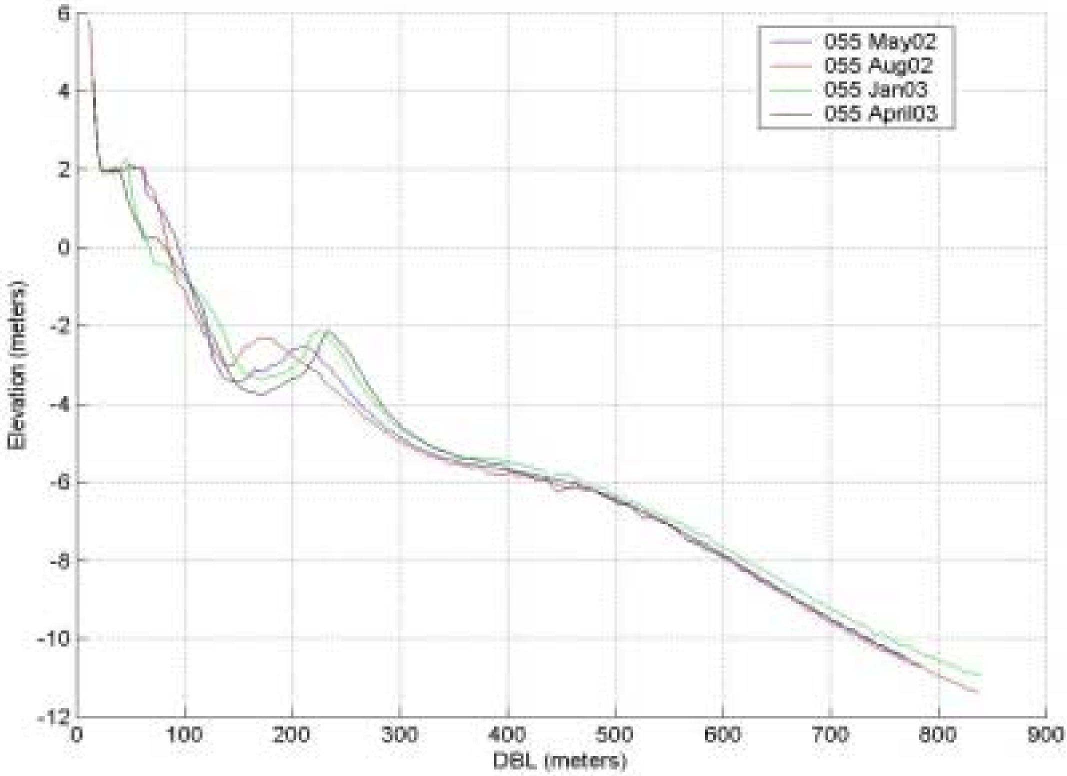
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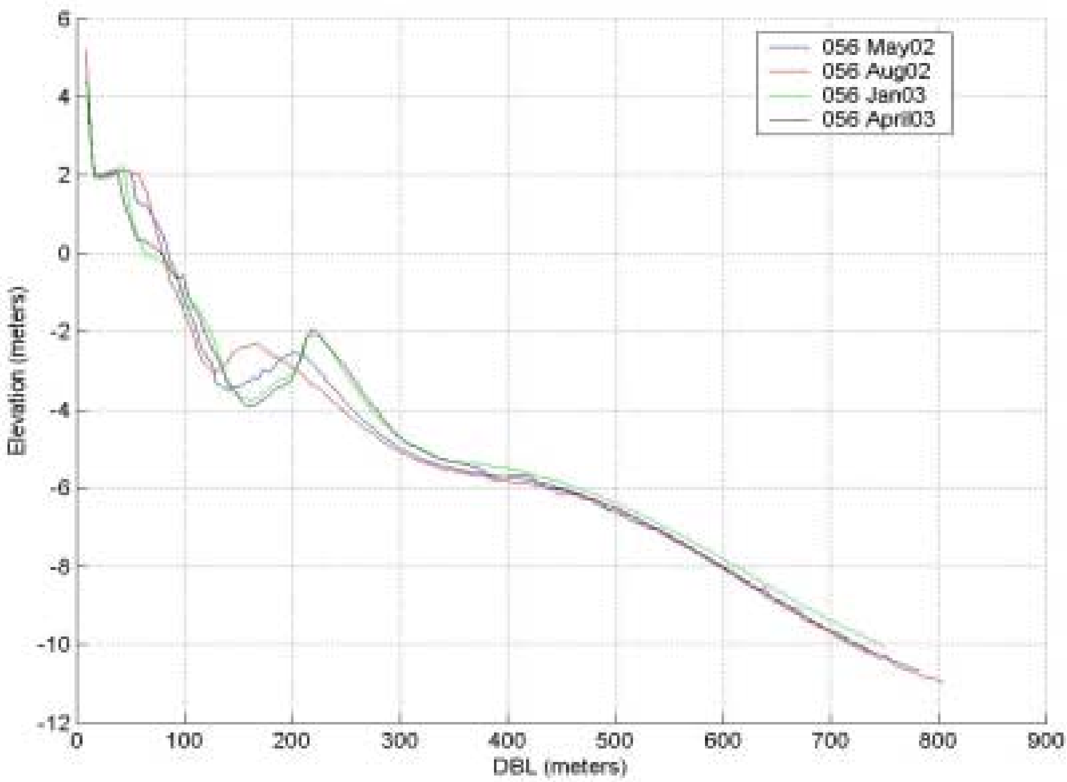
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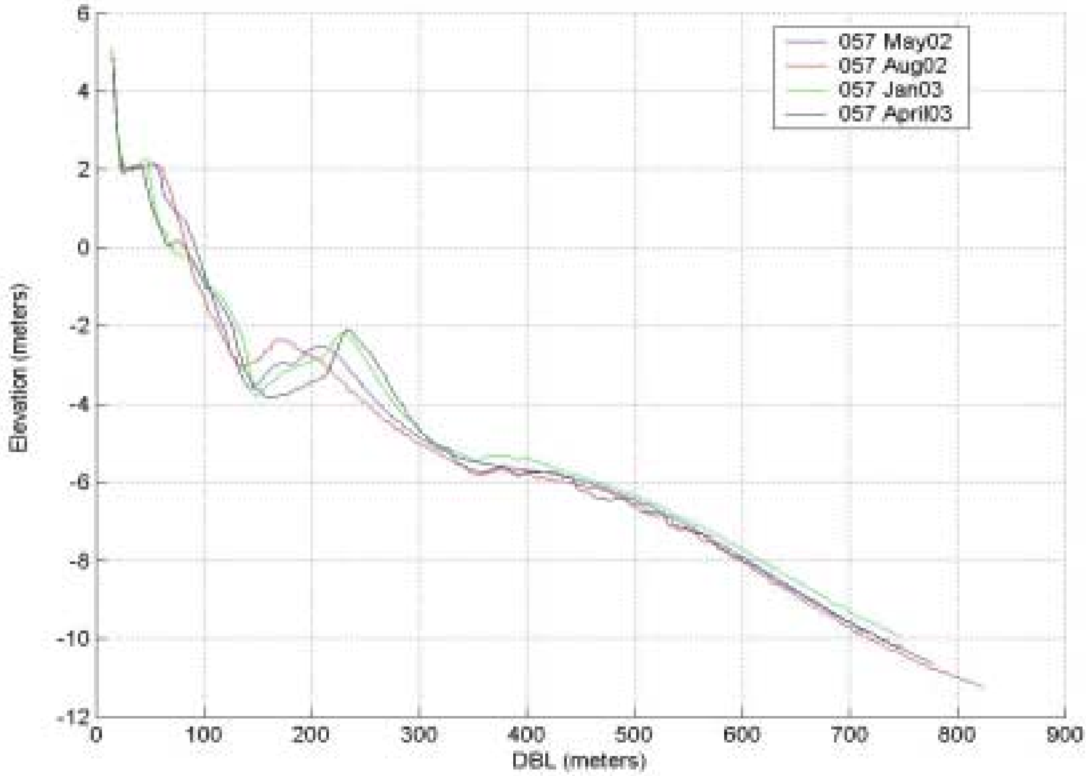
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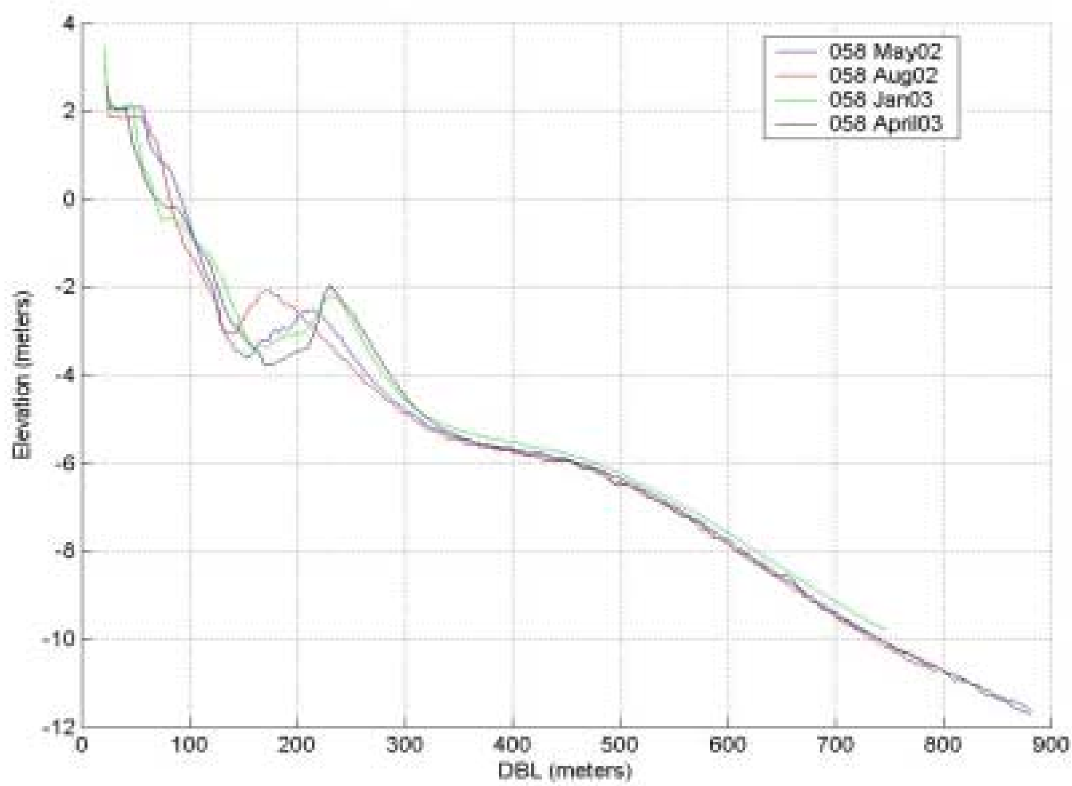
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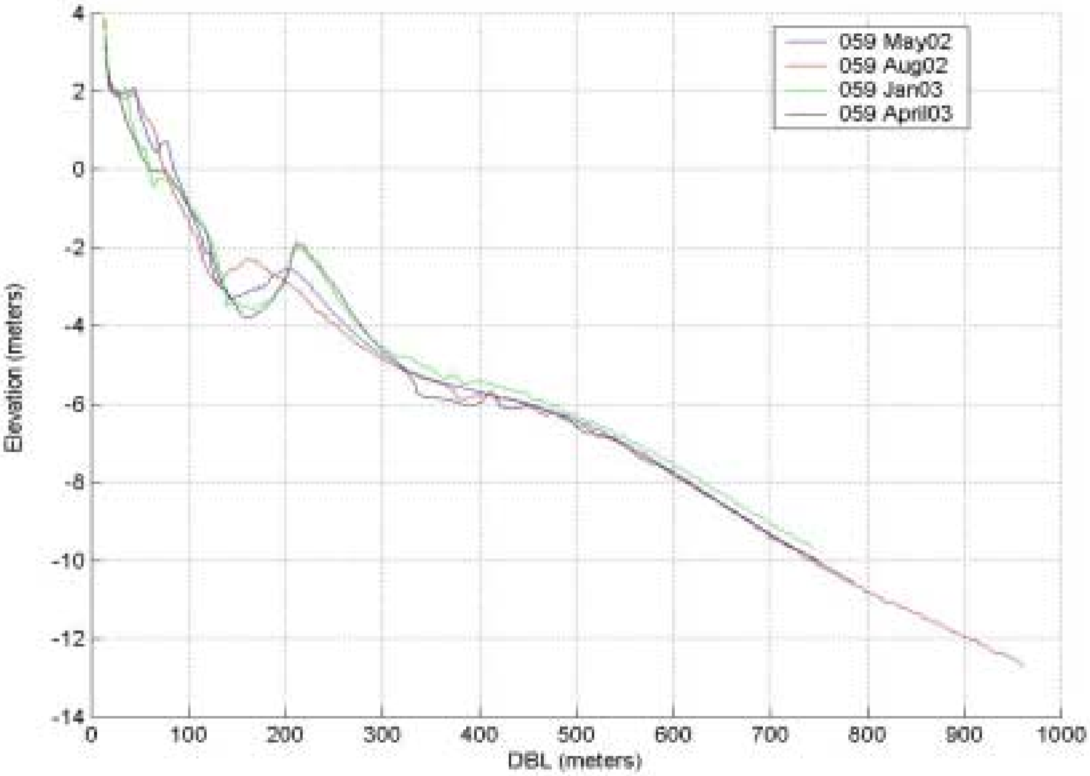
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Elevation (meters)
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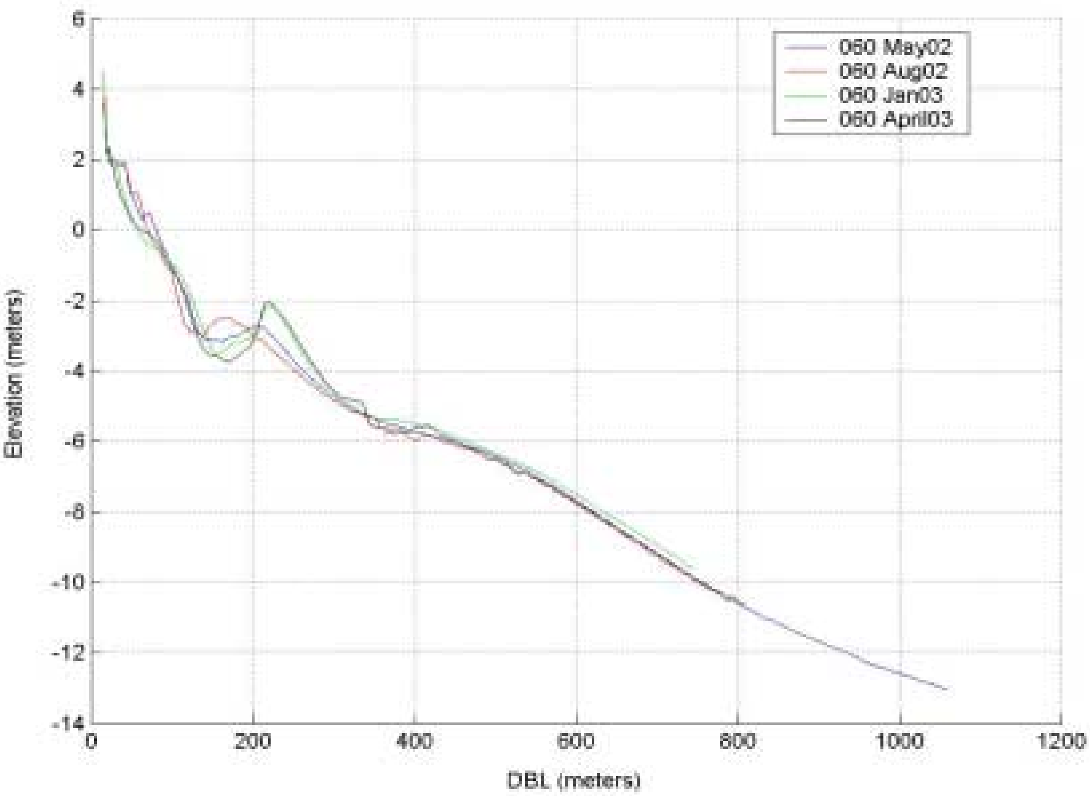
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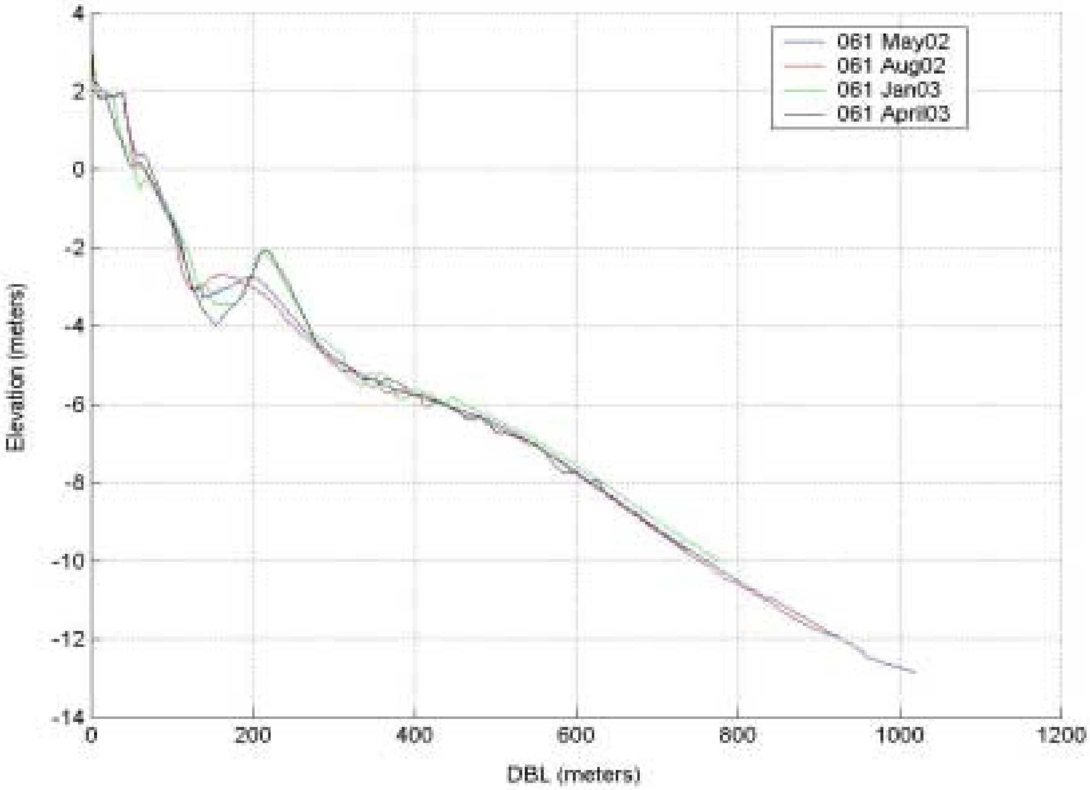

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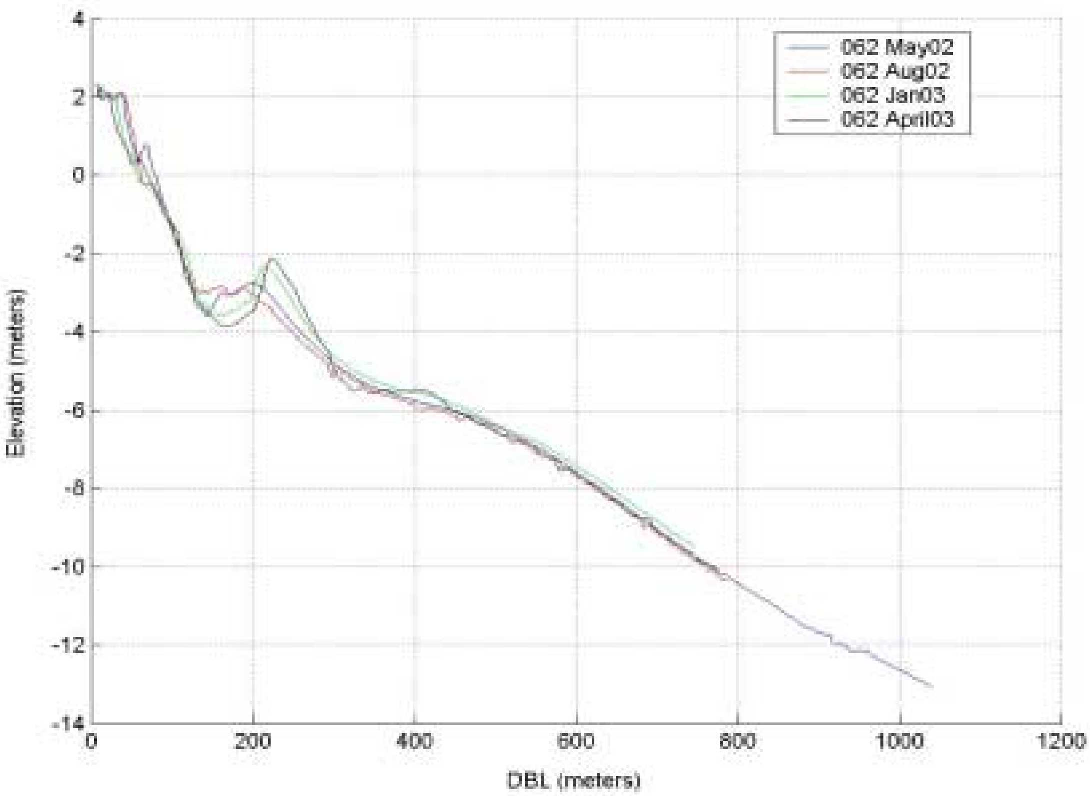

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Elevation (meters)
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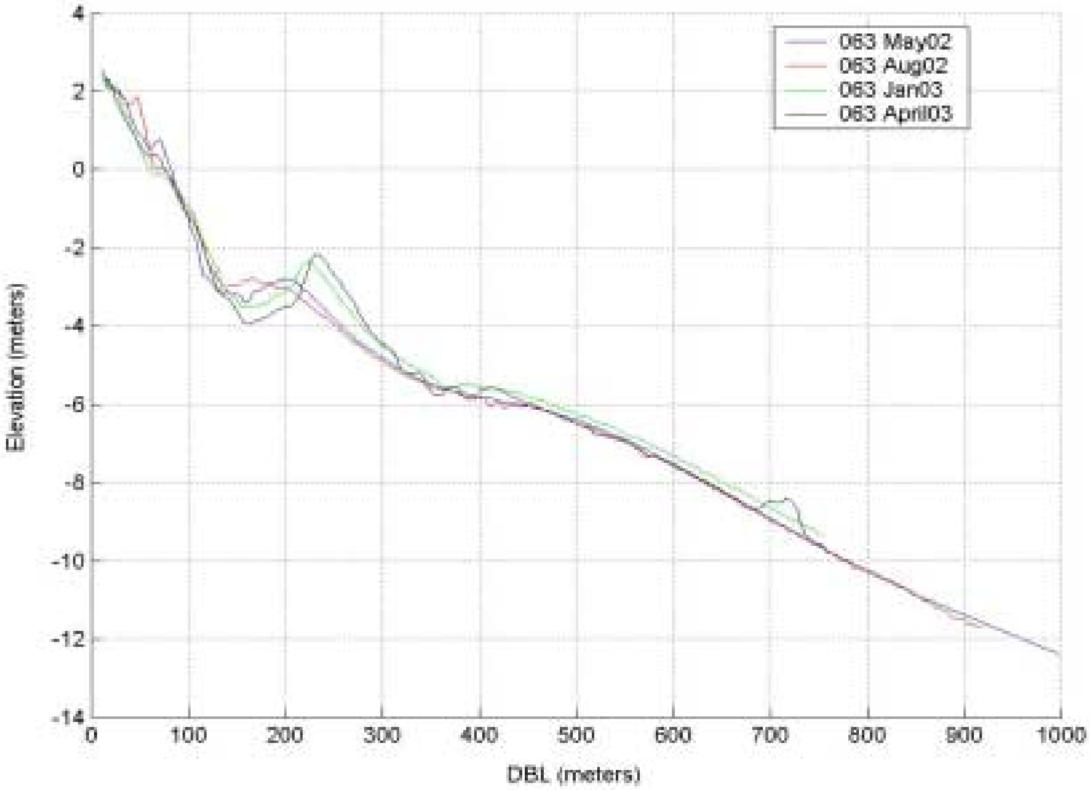
063 May02
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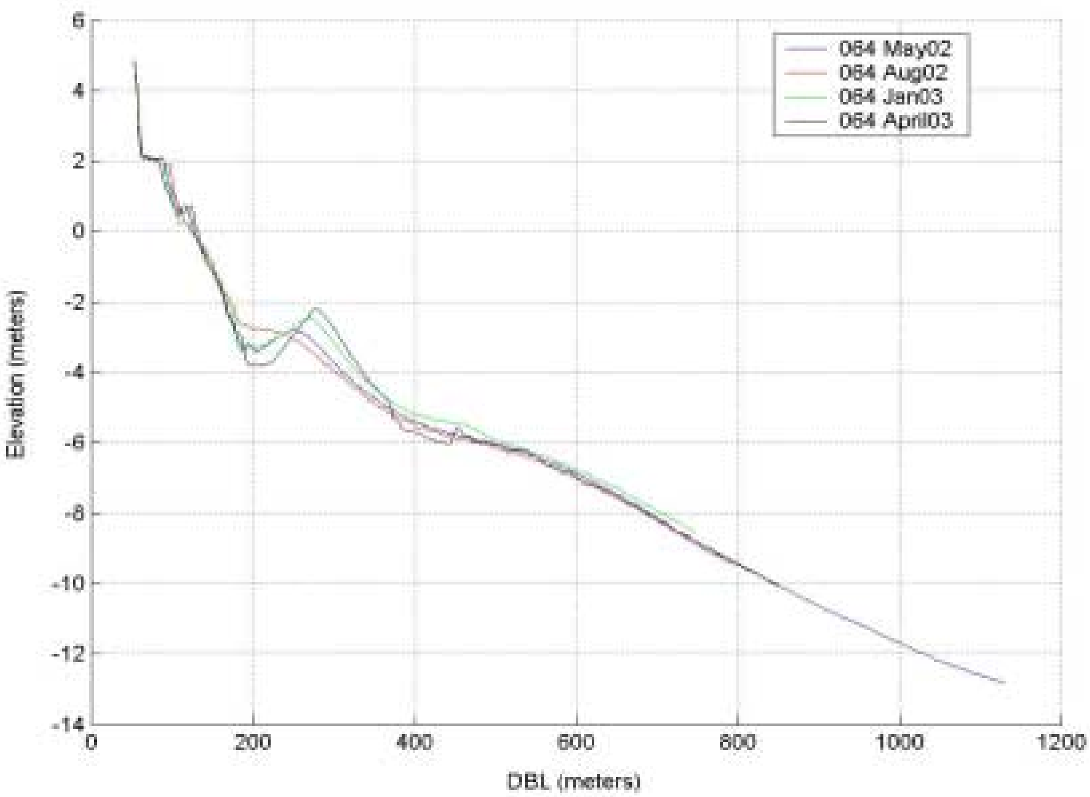
Elevation (meters)
DBL (meters)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064 Jan03
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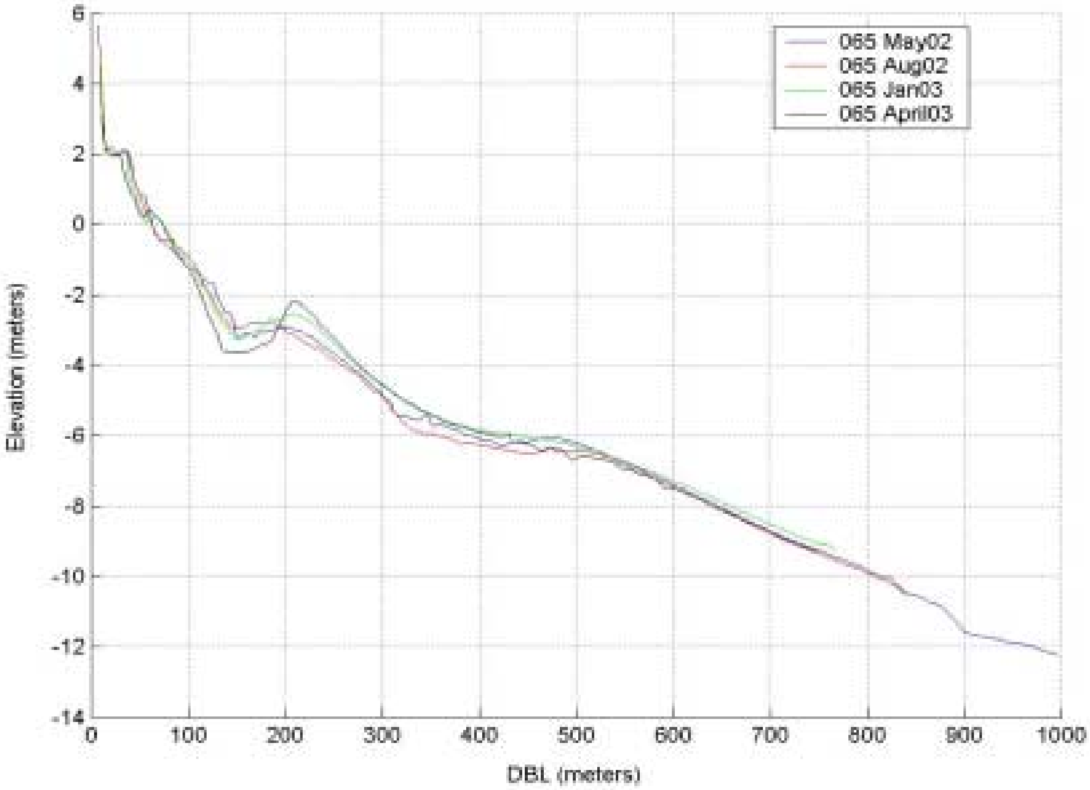
Elevation (meters)
DBL (meters)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065 April03
Elevation (meters)
DBL (meters)
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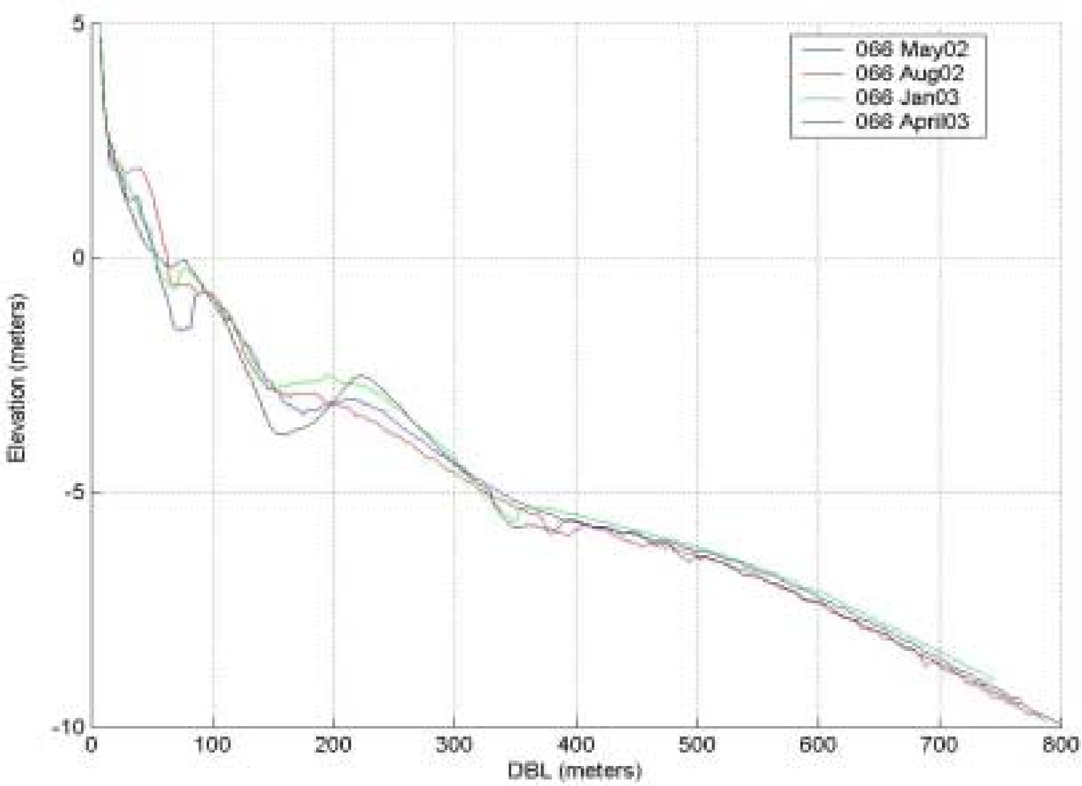
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DBL (meters)
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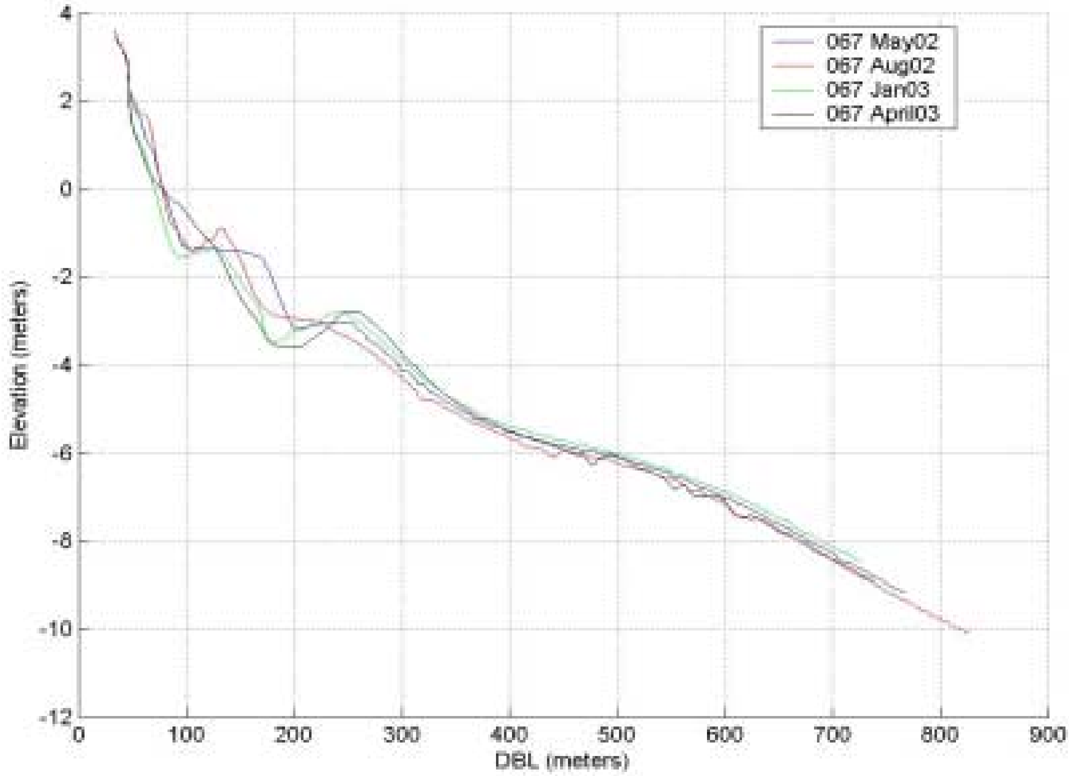
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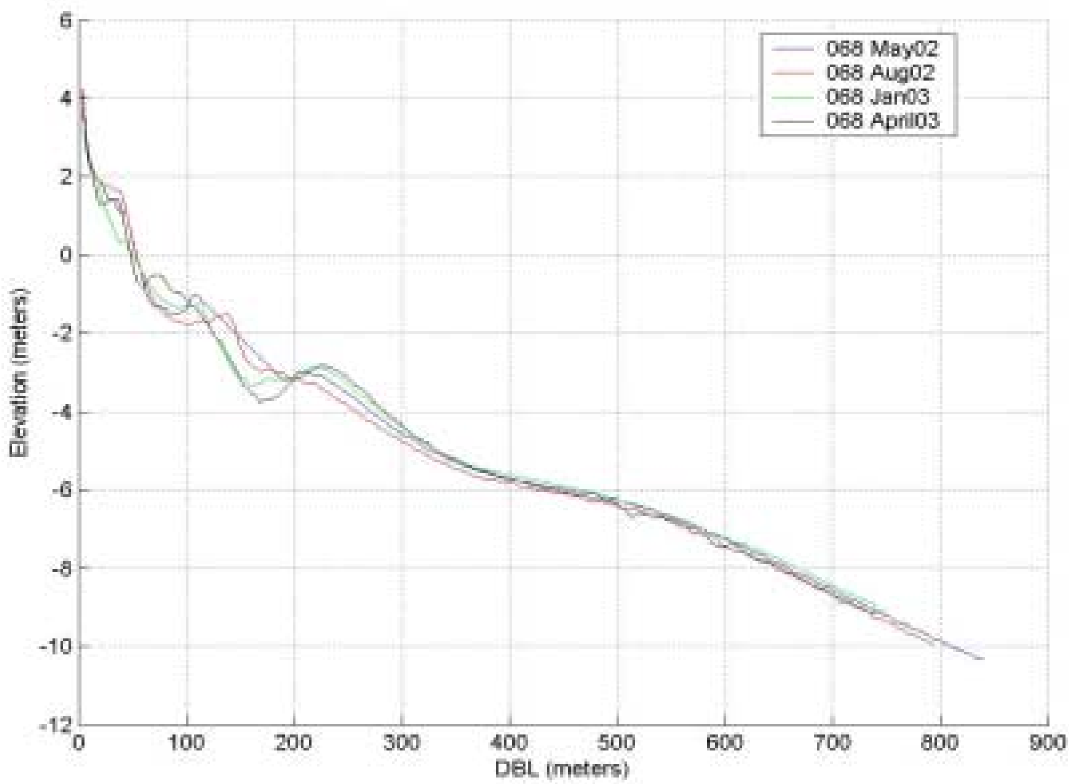
DBL (meters)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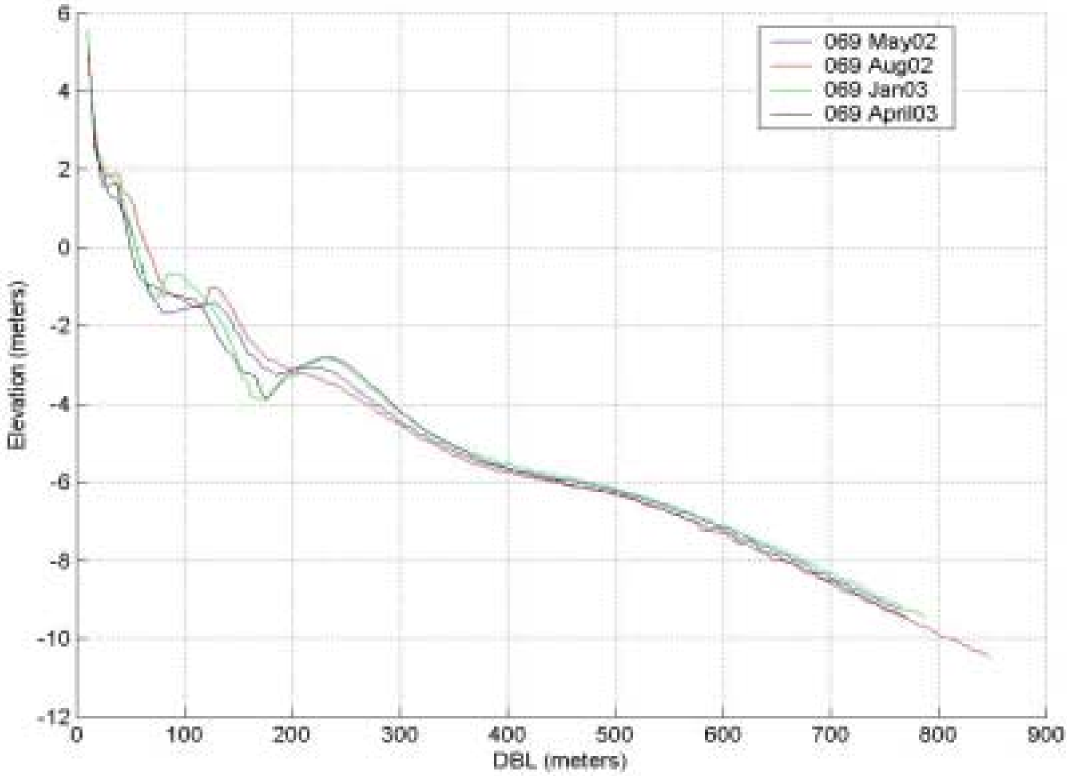
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DBL (meters)
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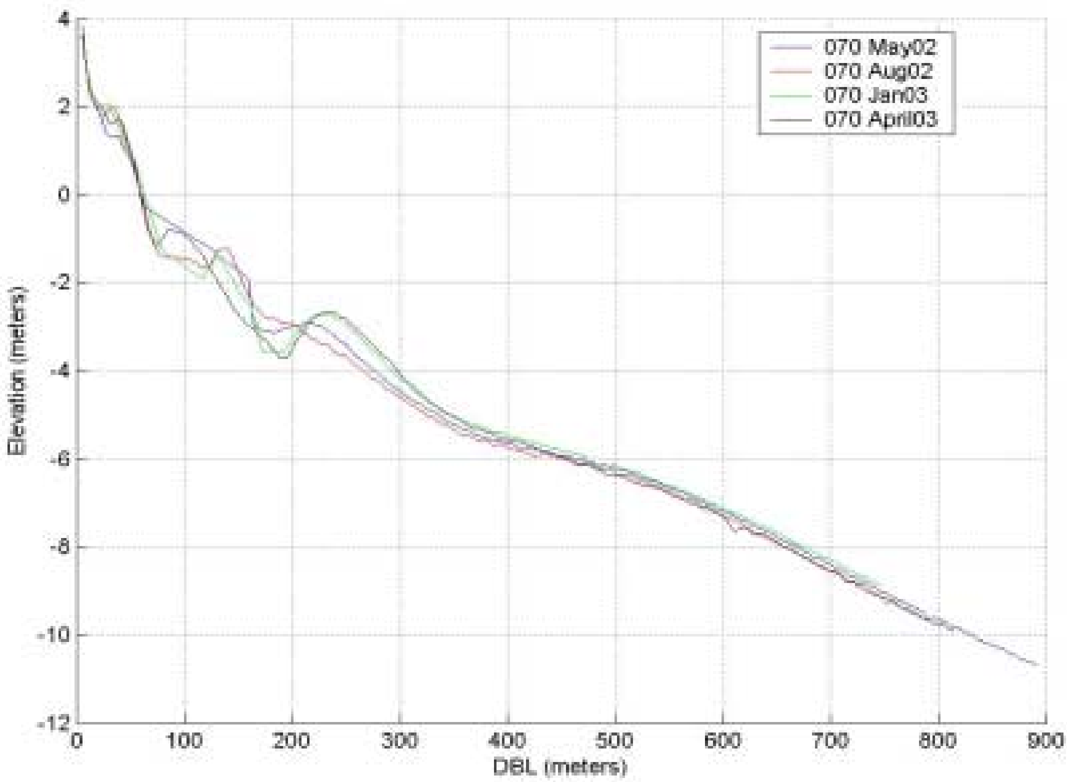
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DBL (meters)
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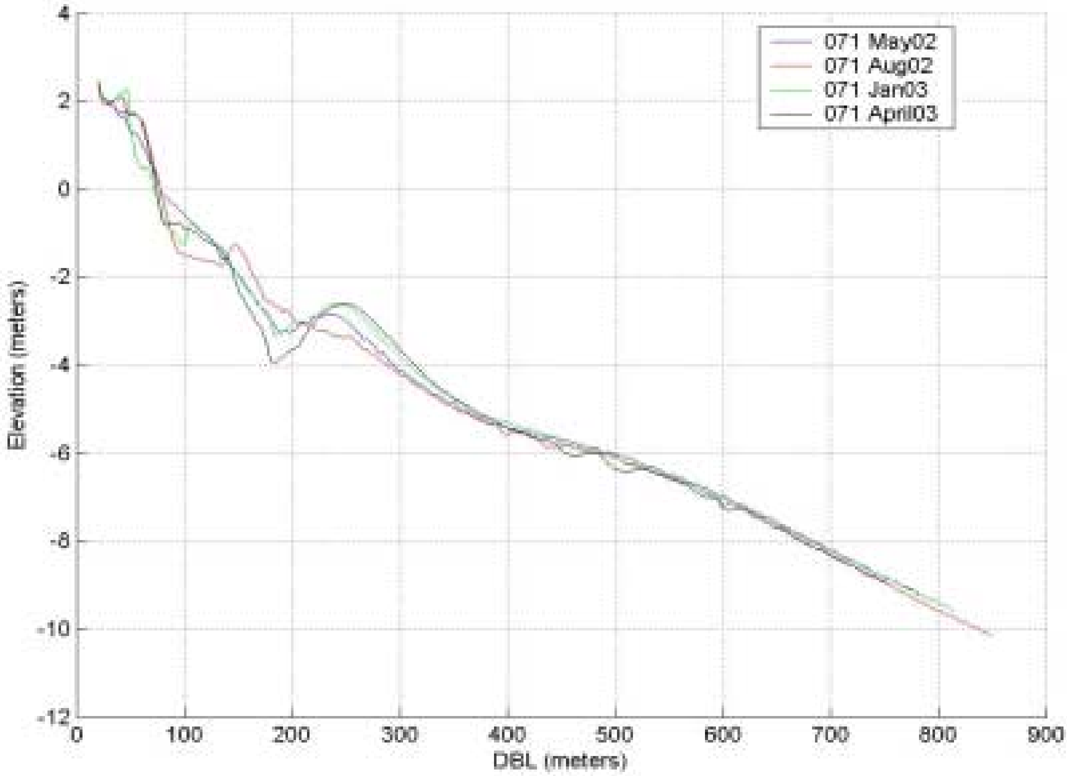
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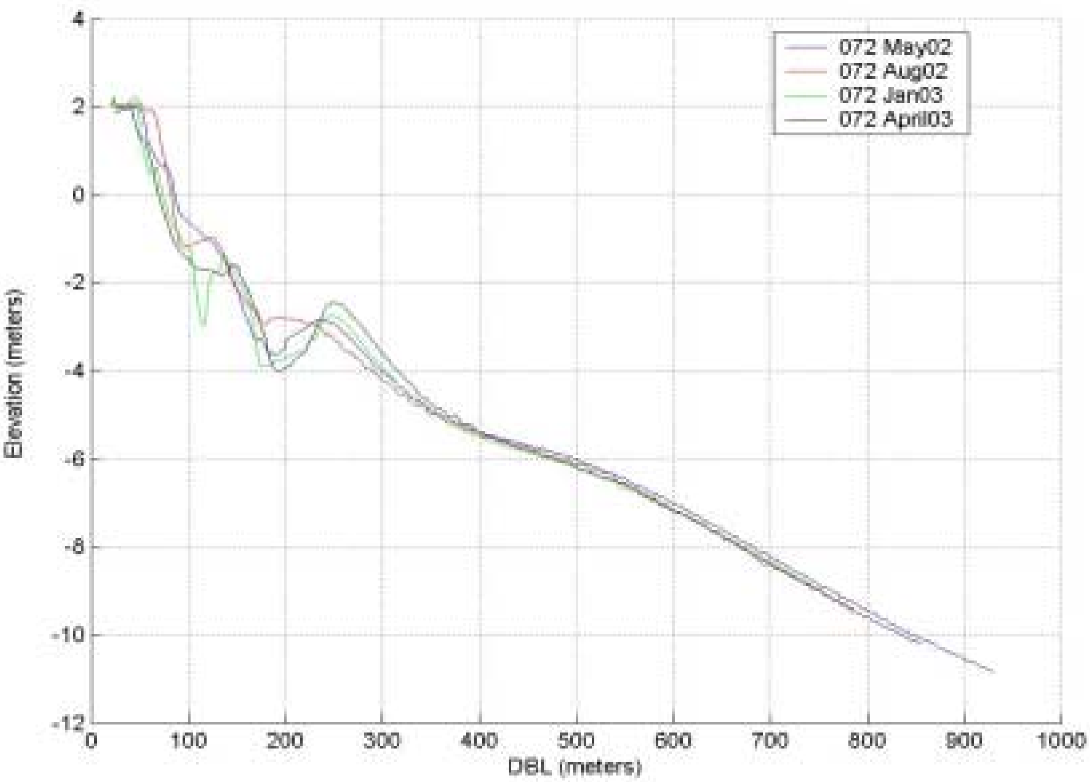
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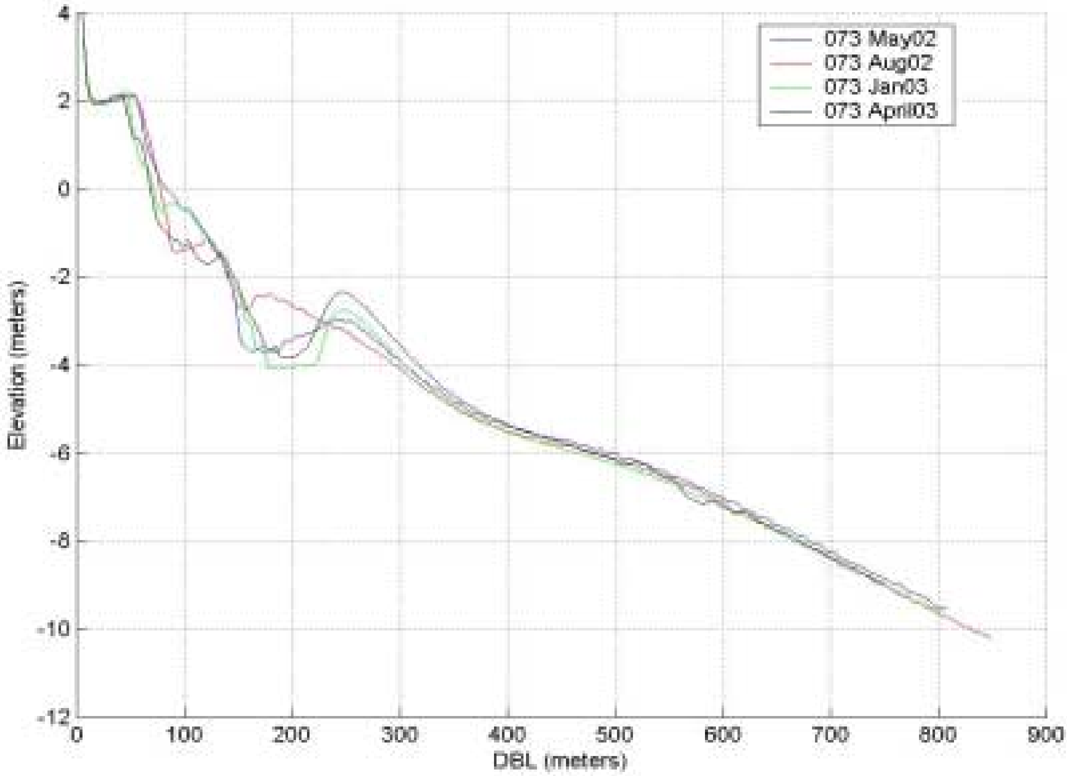
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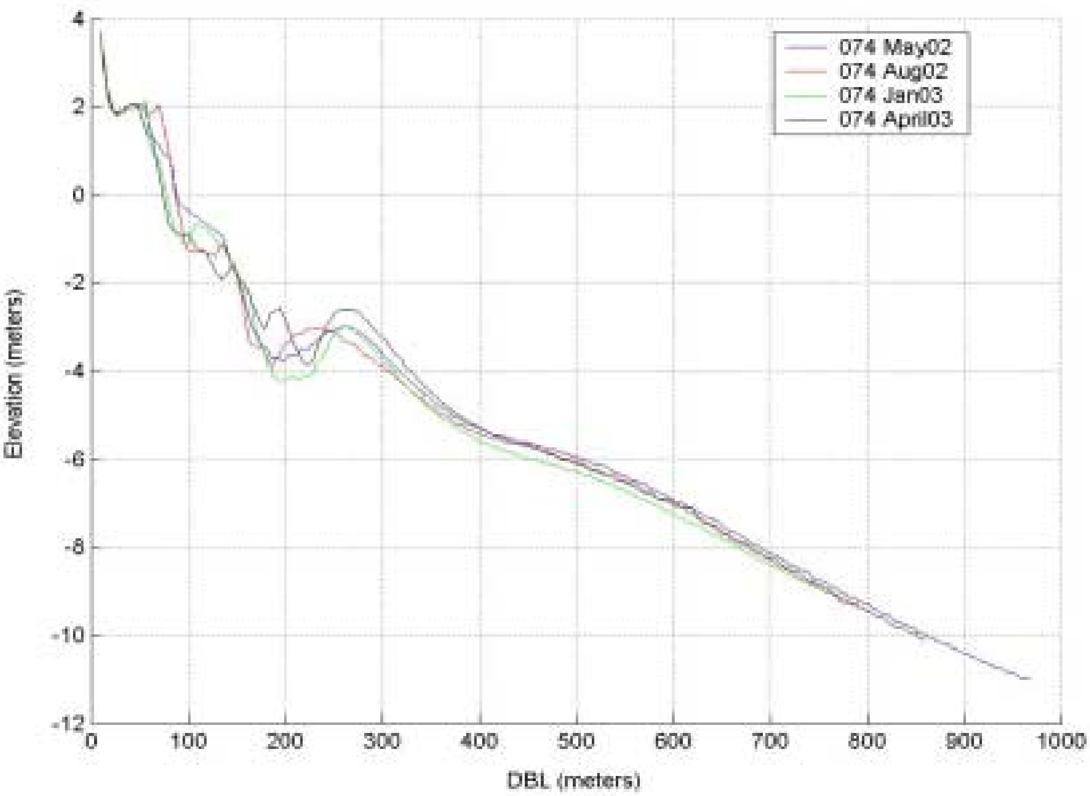
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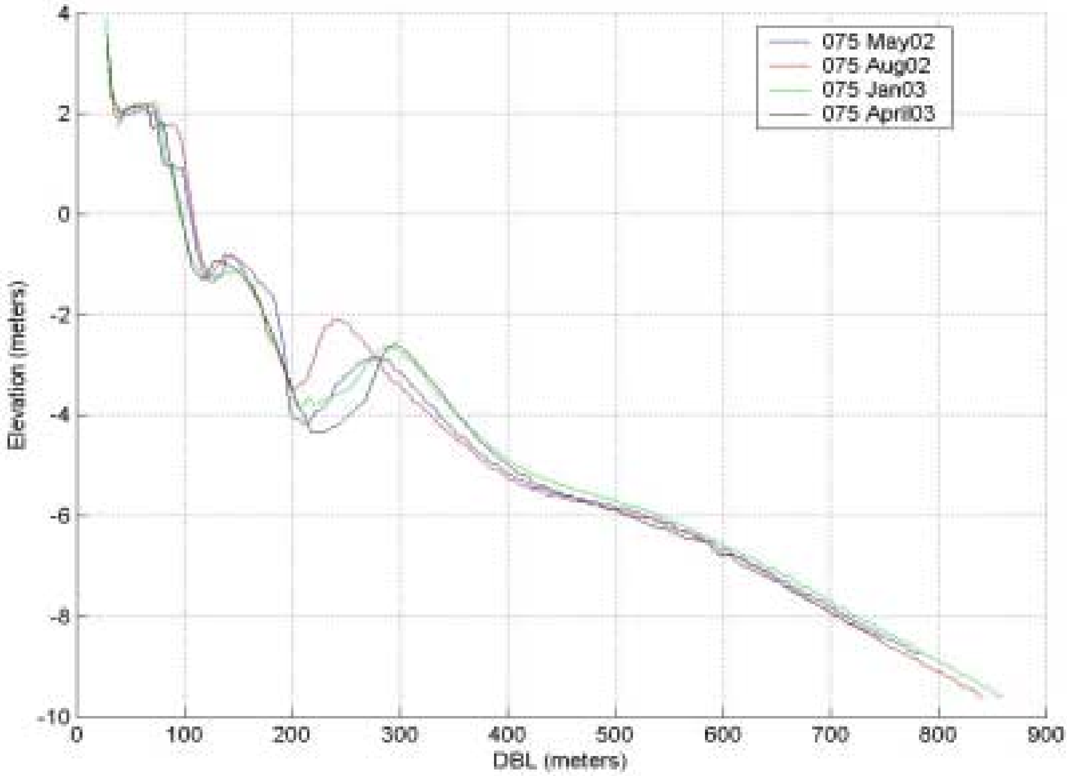
DBL (meters)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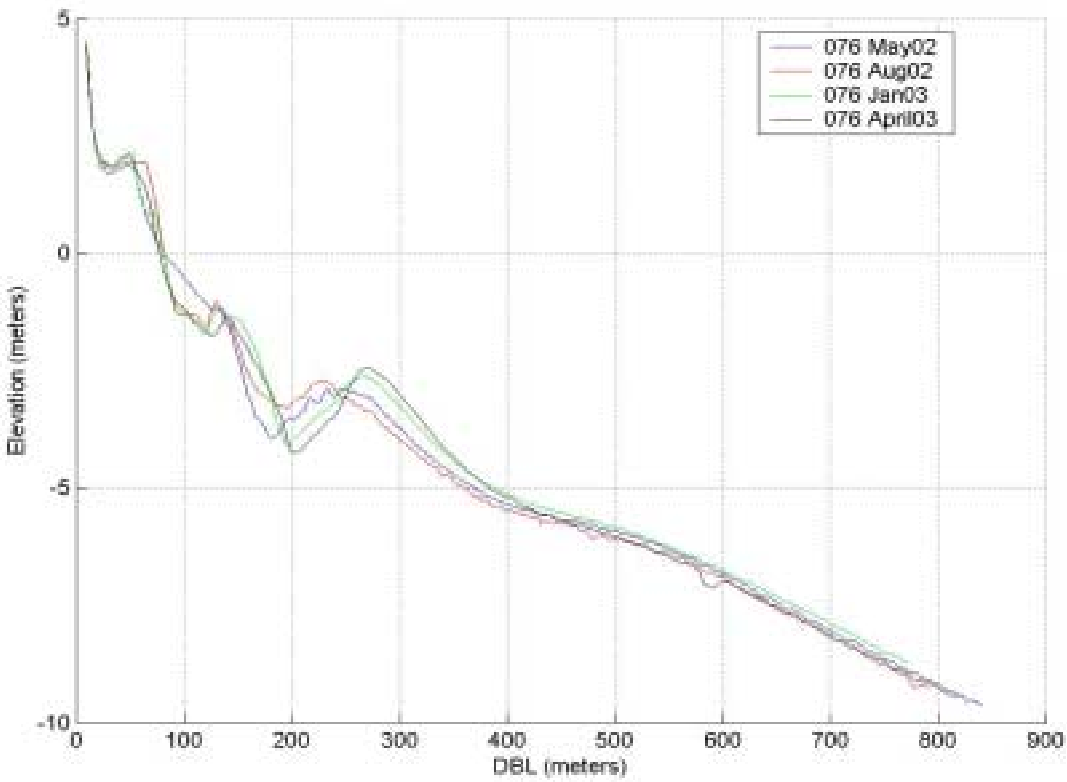
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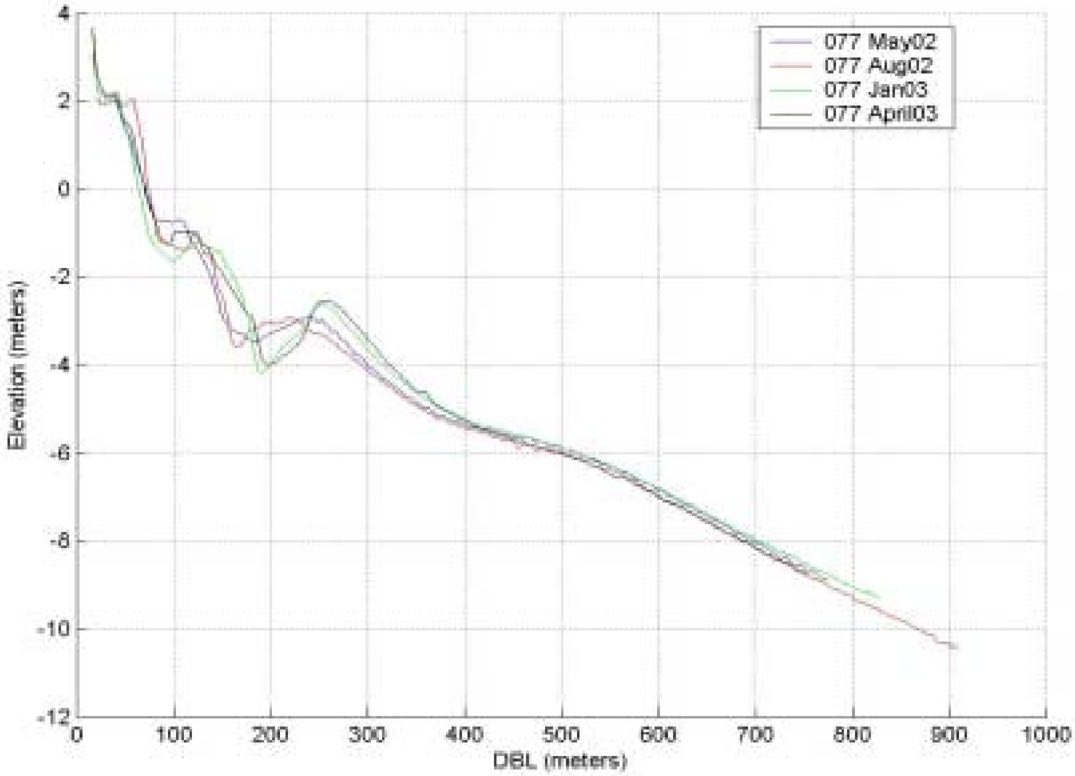

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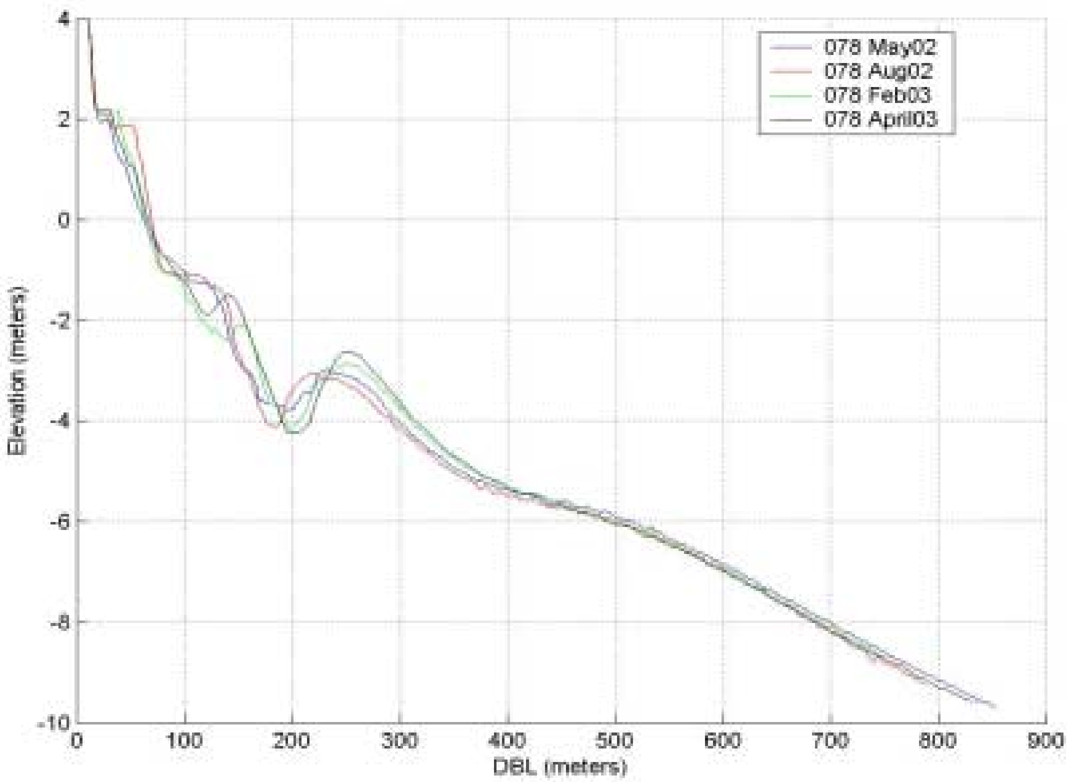
Elevation (meters)
DBL (meters)



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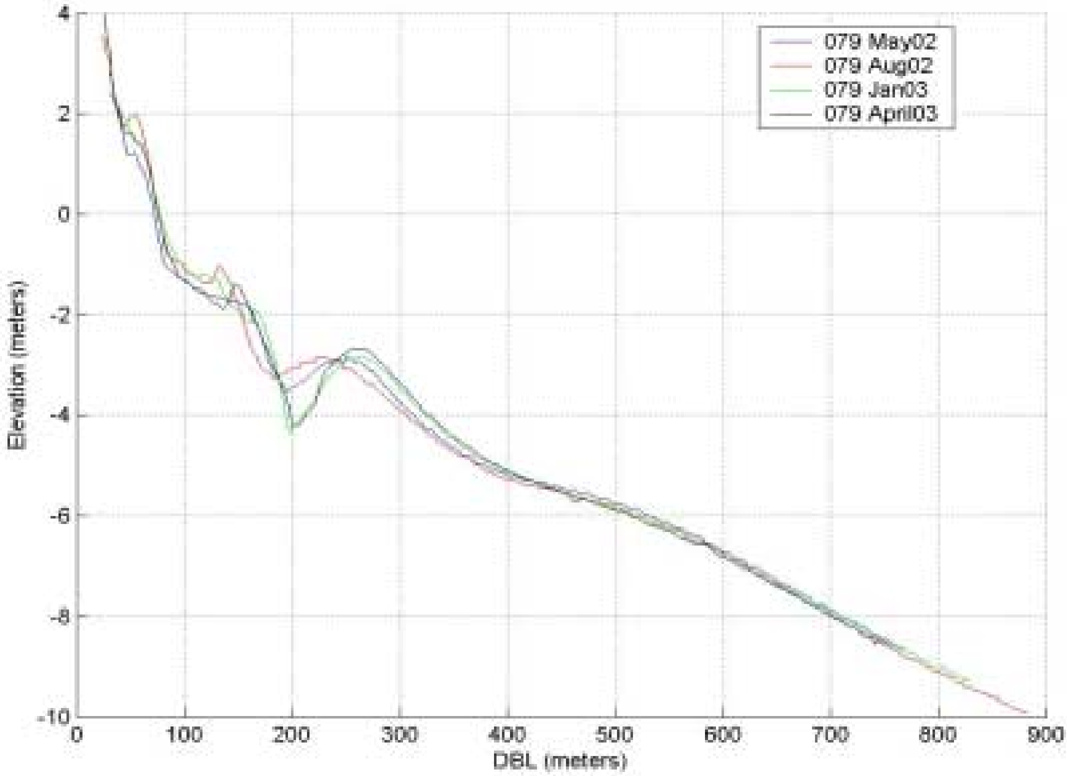
078 April03
Elevation (meters)
DBL (meters)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079 Jan03
079 April03
Elevation (meters)
DBL (meters)
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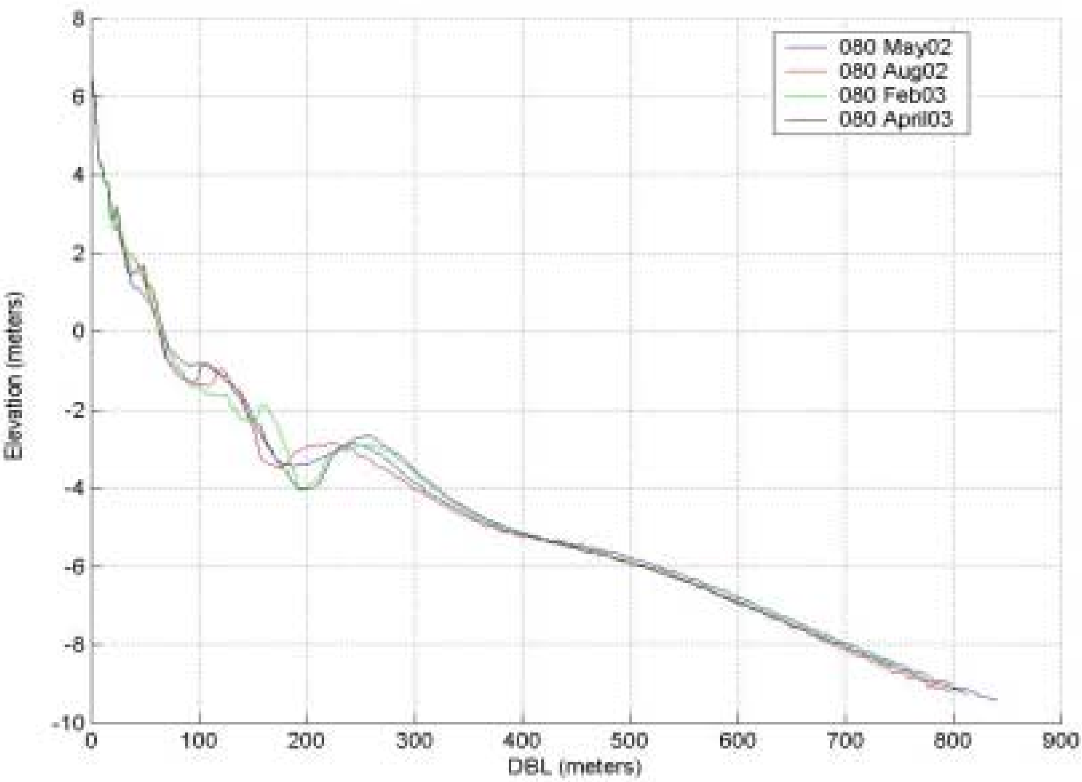
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080 Feb03
080 April03
Elevation (meters)
DBL (meters)
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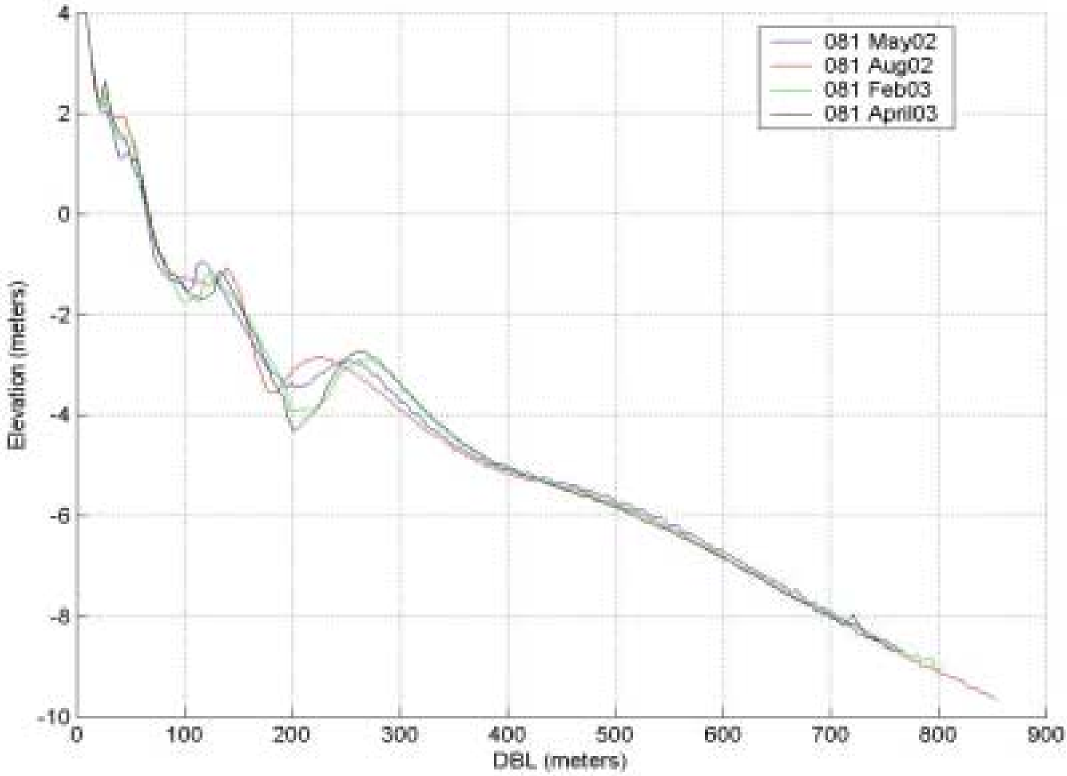
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081 Feb03
081 April03
Elevation (meters)
DBL (meters)
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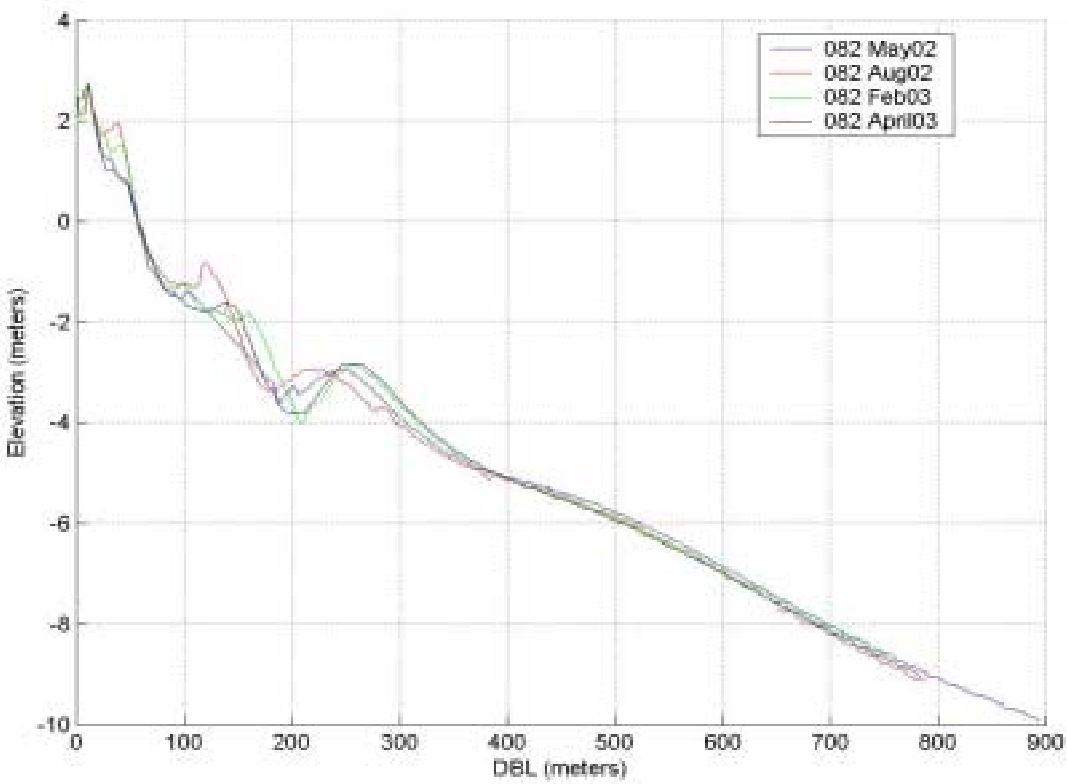
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082 Aug02
082 Feb03
082 April03
Elevation (meters)
DBL (meters)
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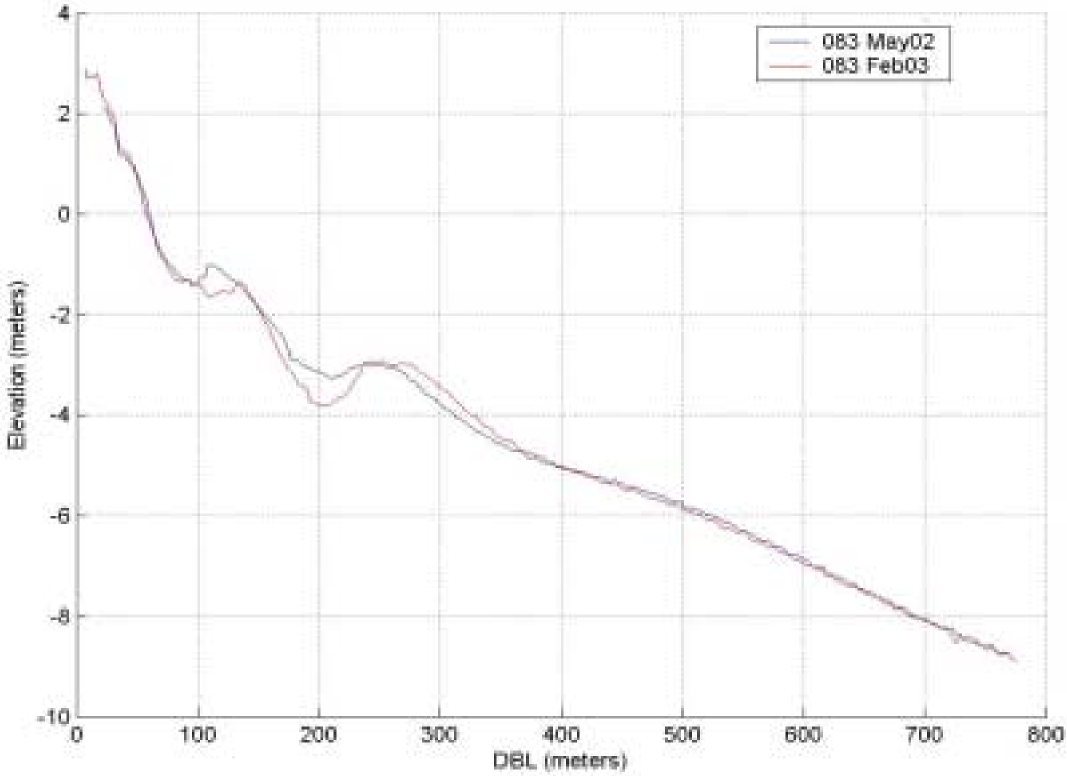
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083 Feb03
Elevation (meters)
DBL (meters)
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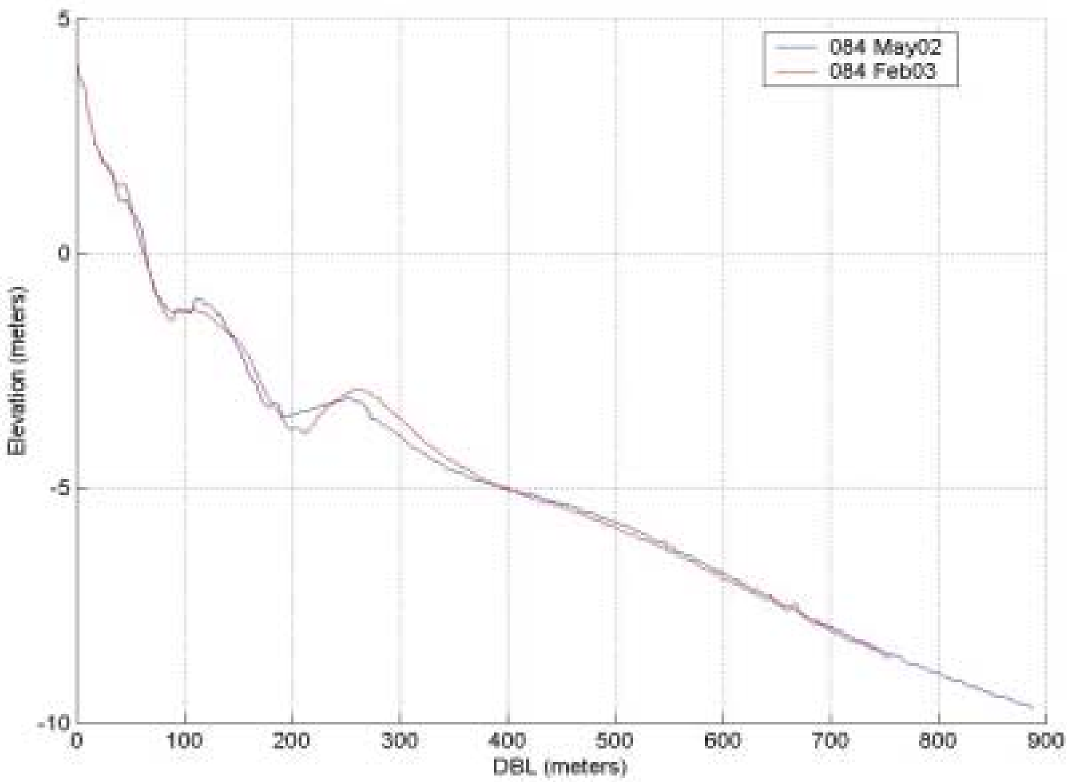
084 May02
084 Feb03
Elevation (meters)
DBL (meters)
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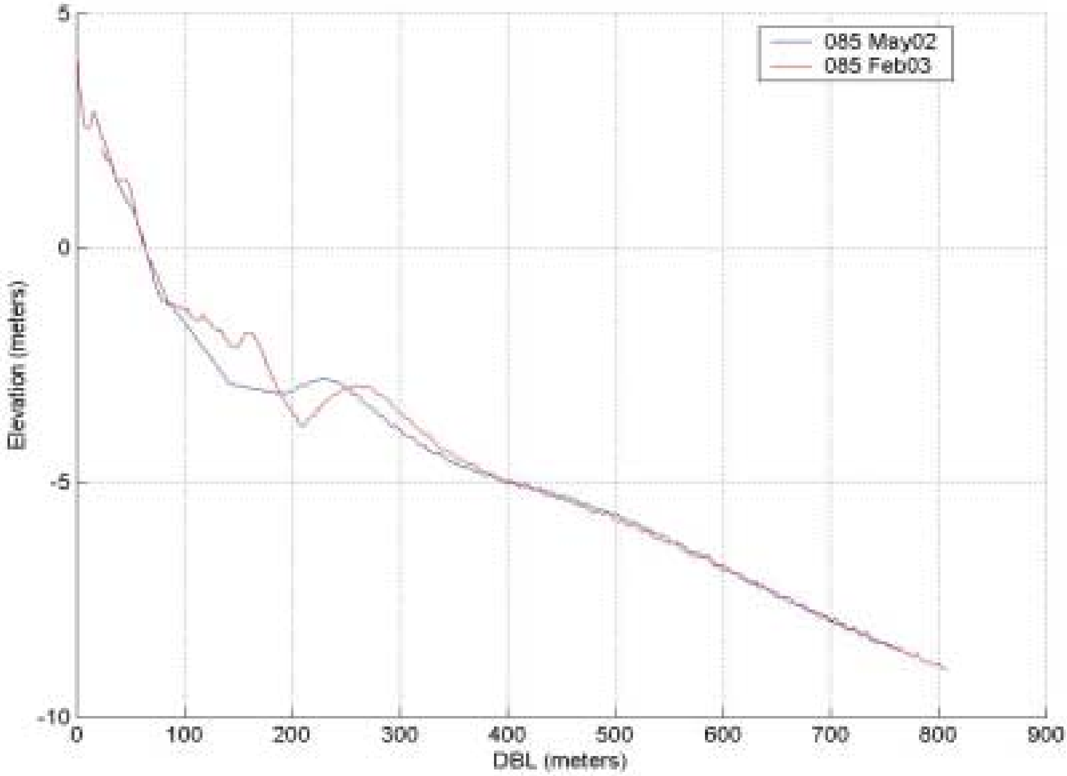
085 May02
085 Feb03
Elevation (meters)
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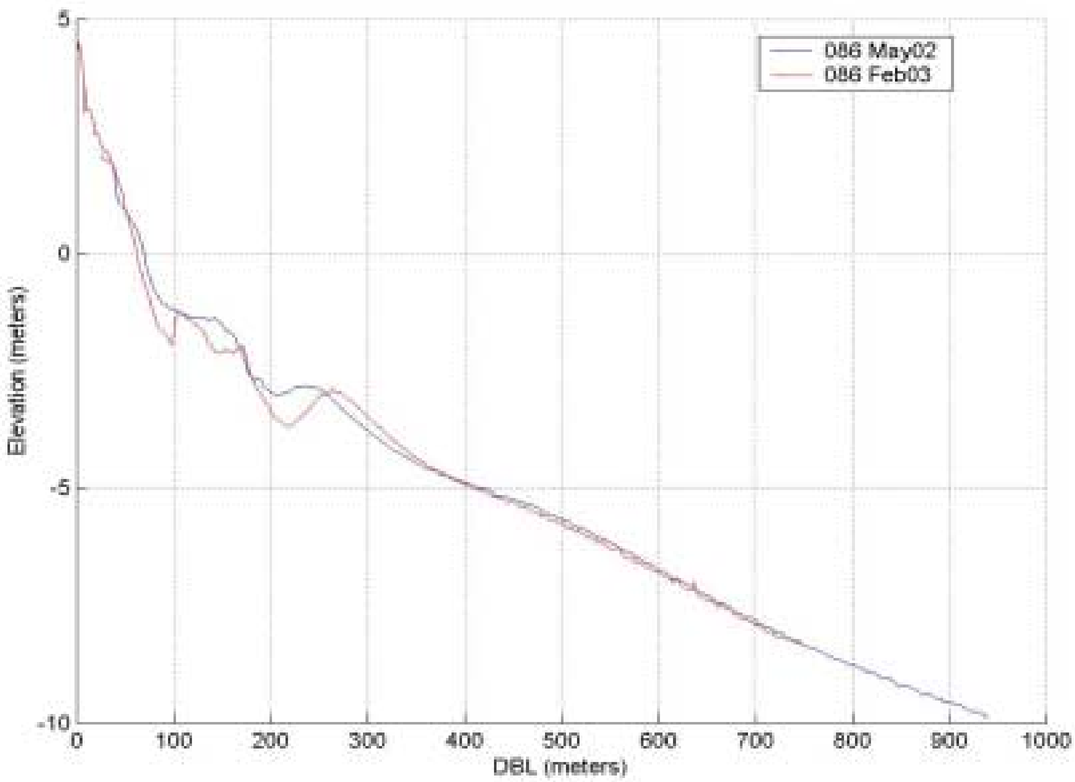
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086 Feb03
Elevation (meters)
DBL (meters)
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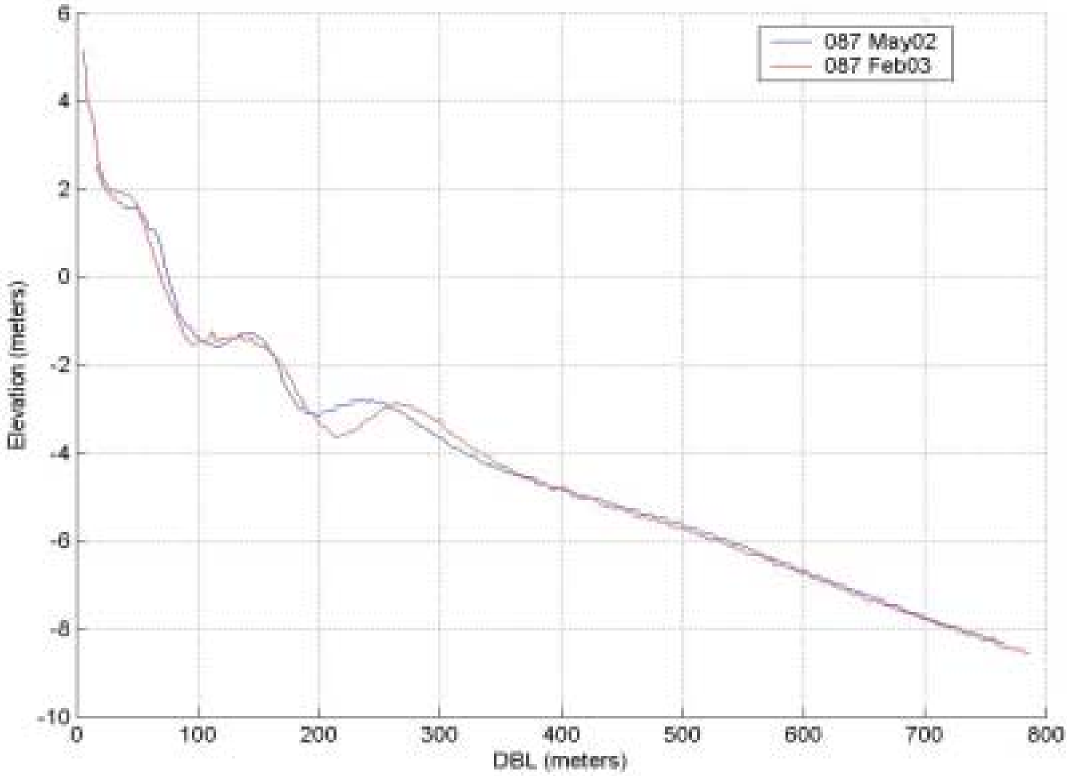

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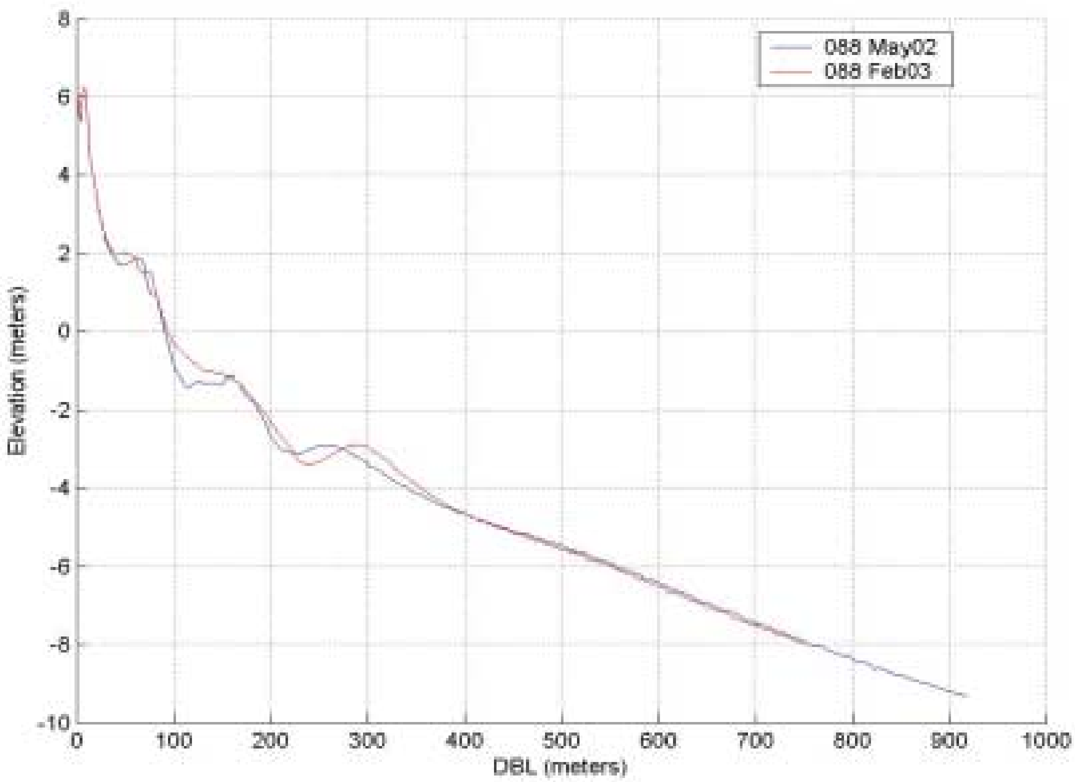
Elevation (meters)
DBL (meters)



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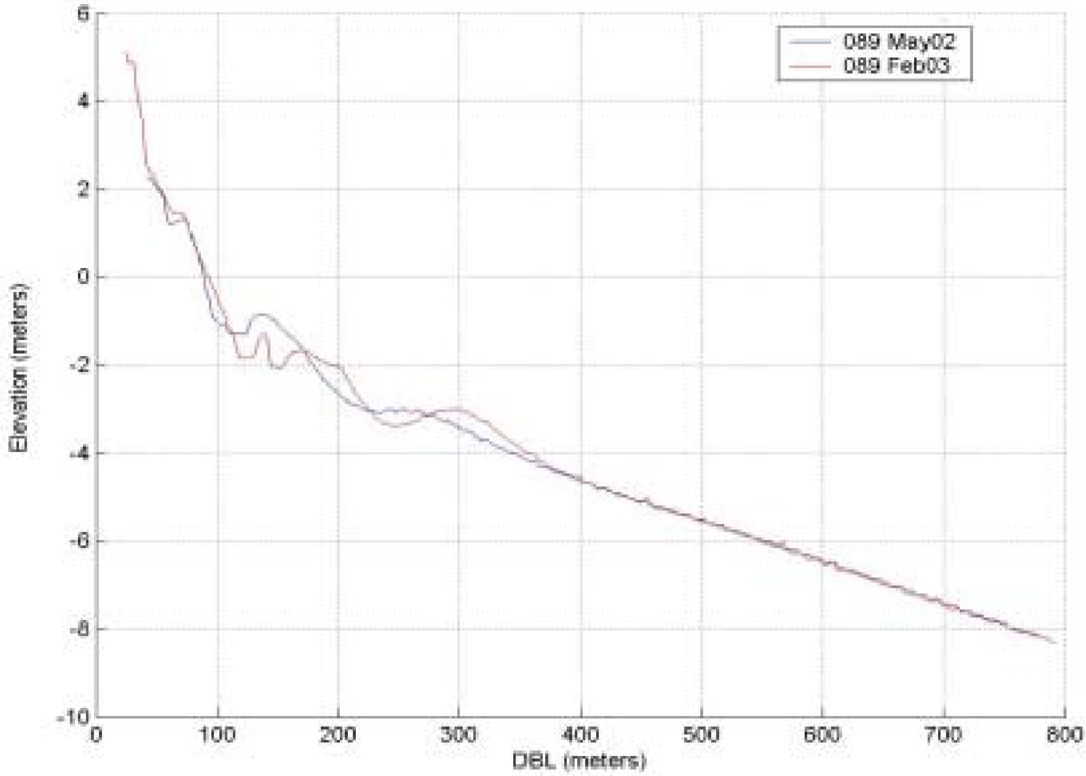
Elevation (meters)
DBL (meters)



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089 Feb03
Elevation (meters)
DBL (meters)
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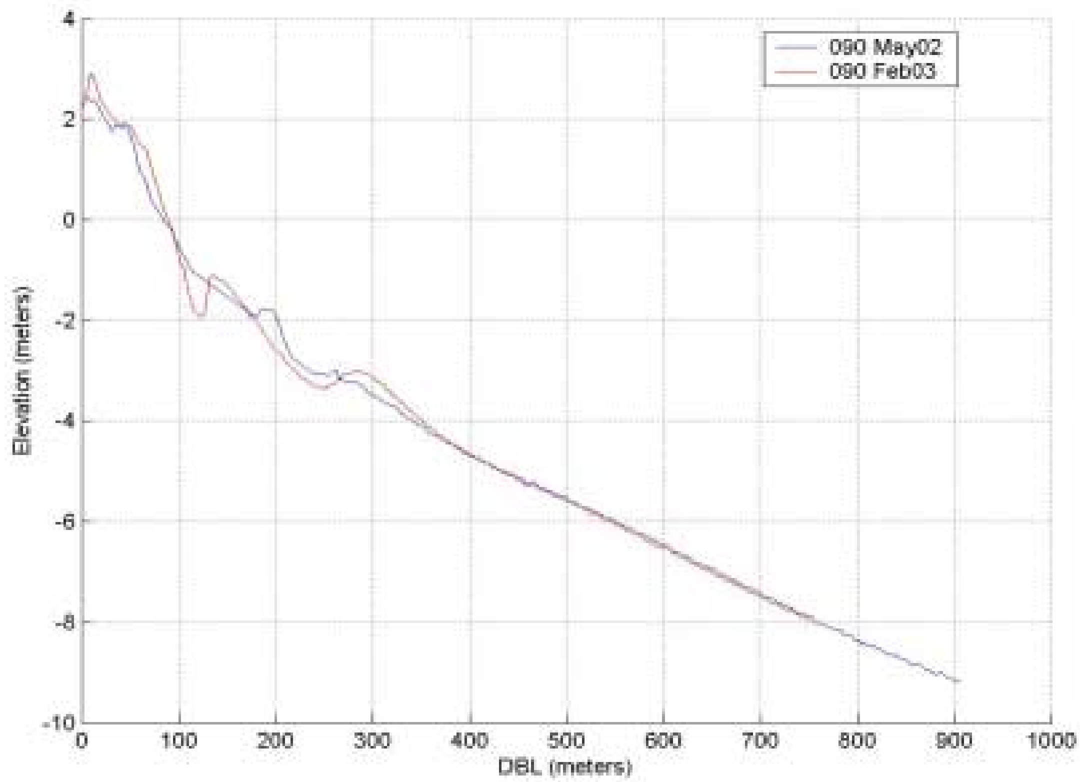

090 May02
090 Feb03
Elevation (meters)
DBL (meters)
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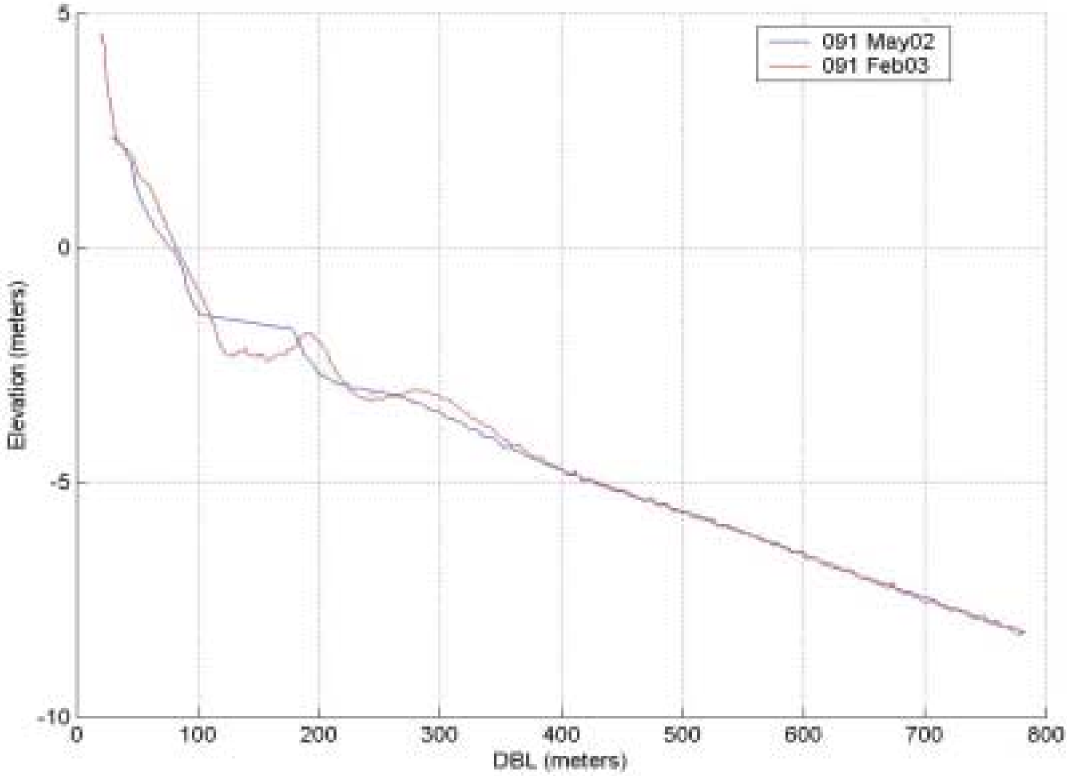
091 May02
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Elevation (meters)
DBL (meters)
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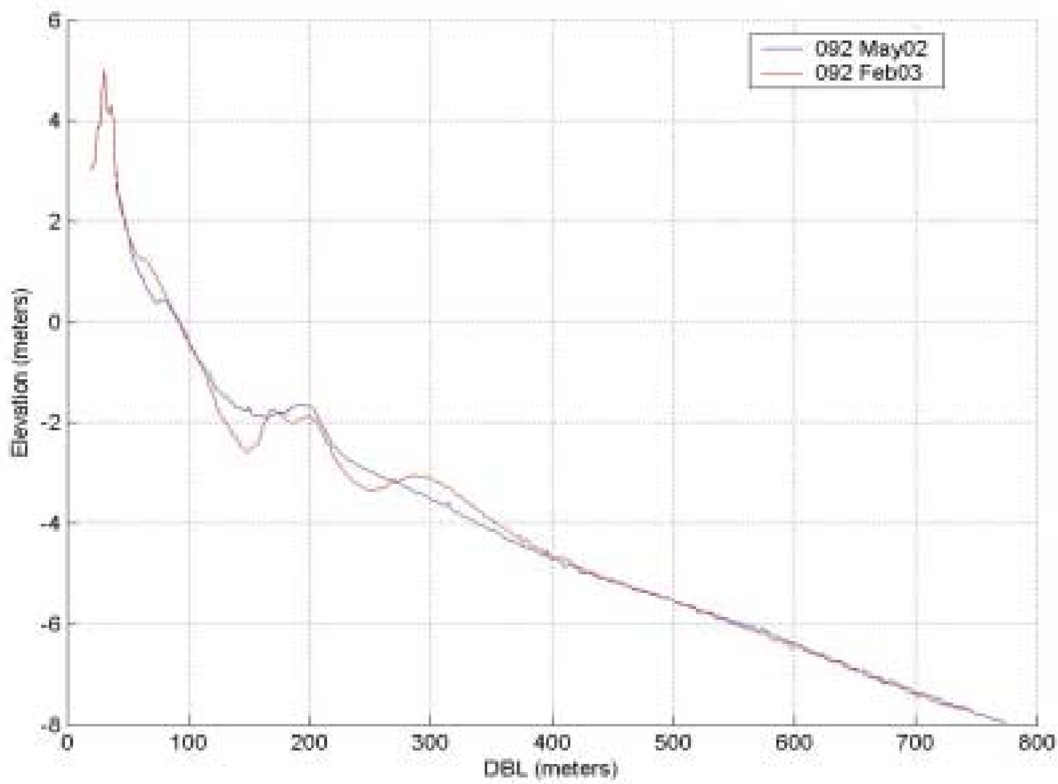
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Elevation (meters)
DBL (meters)
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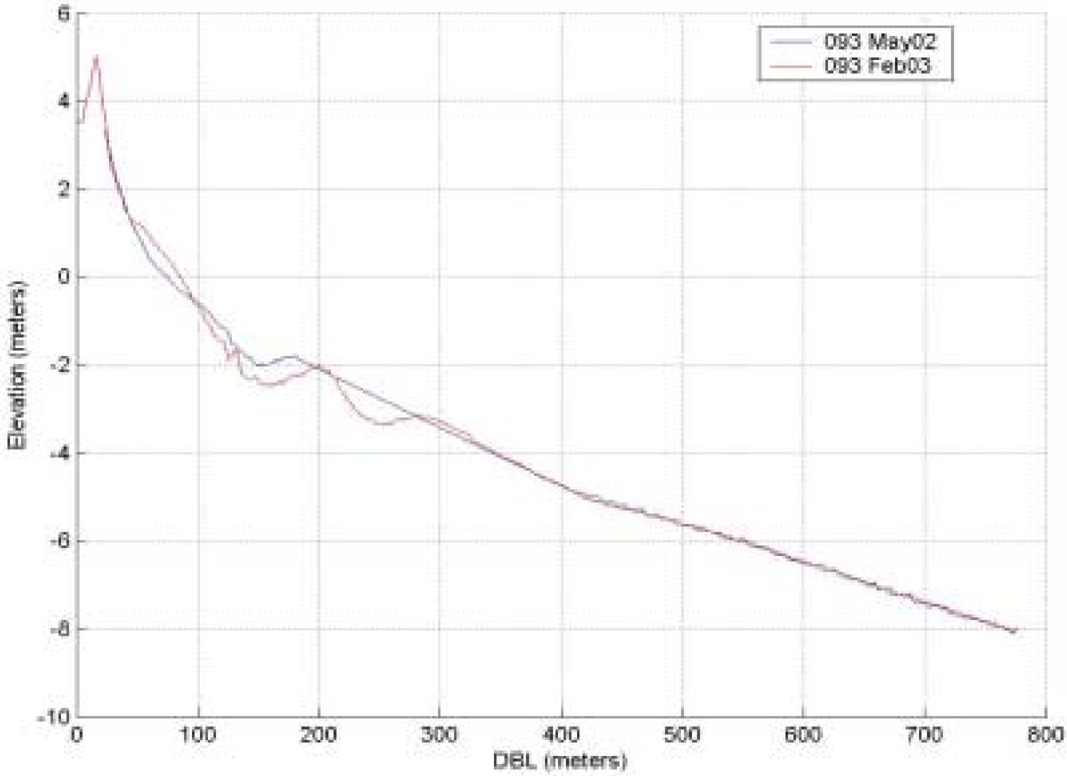
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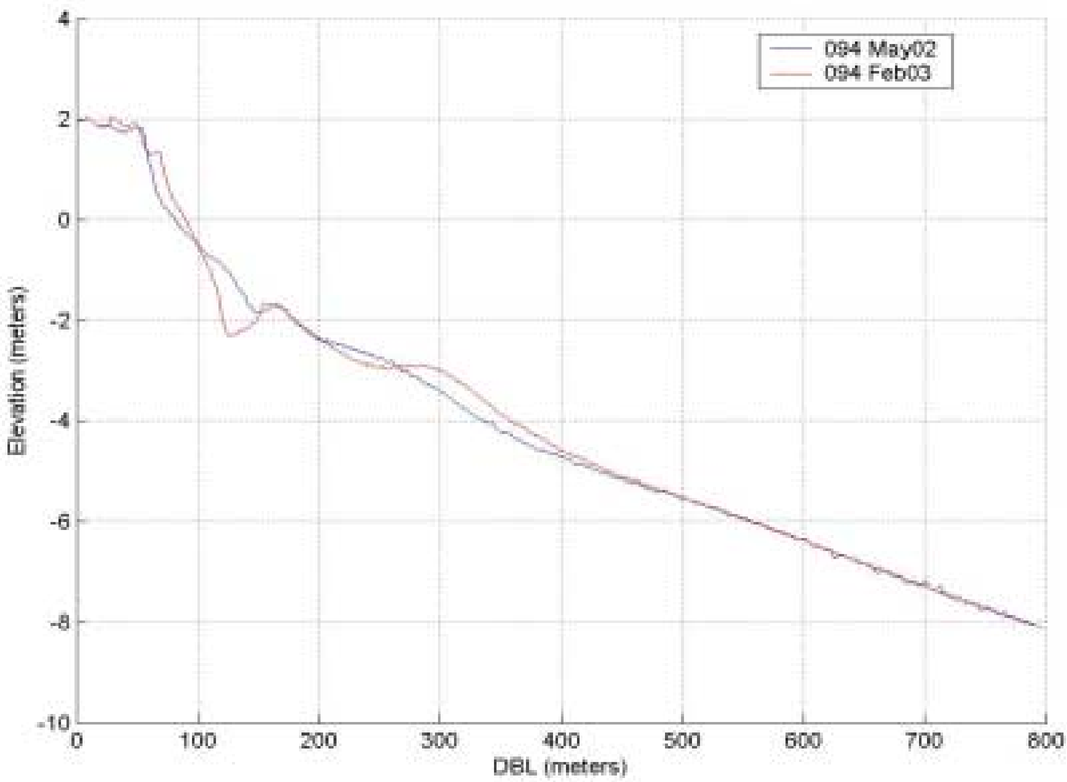
Elevation (meters)
DBL (meters)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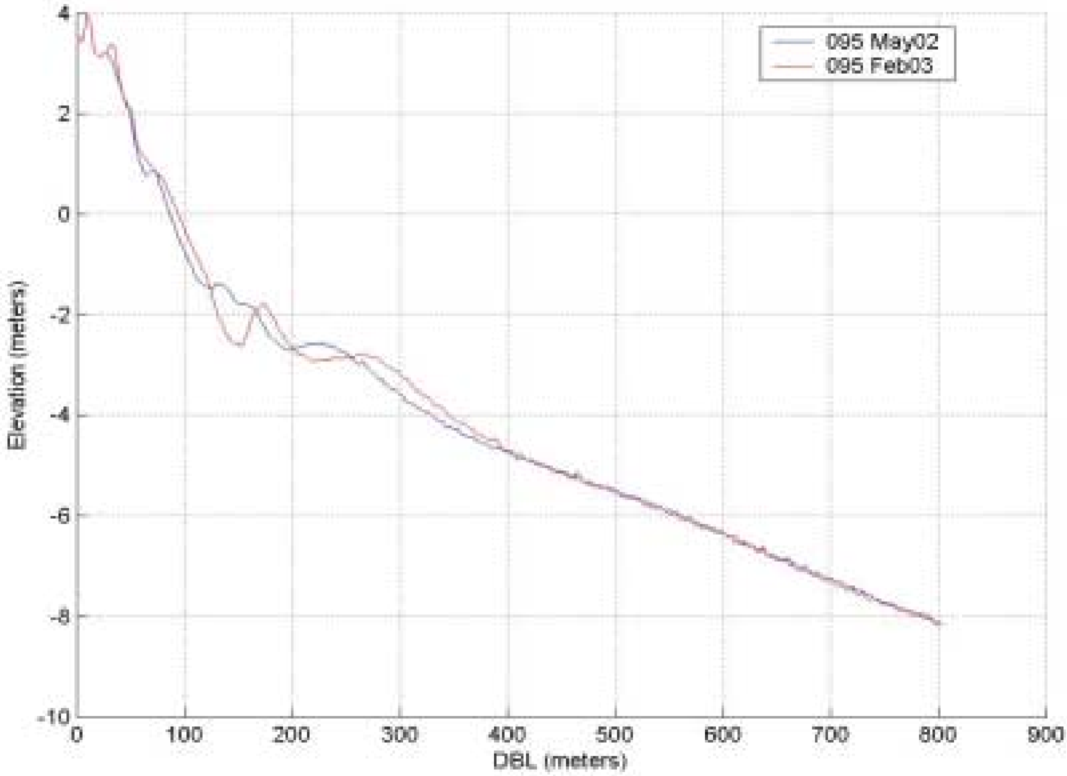
DBL (meters)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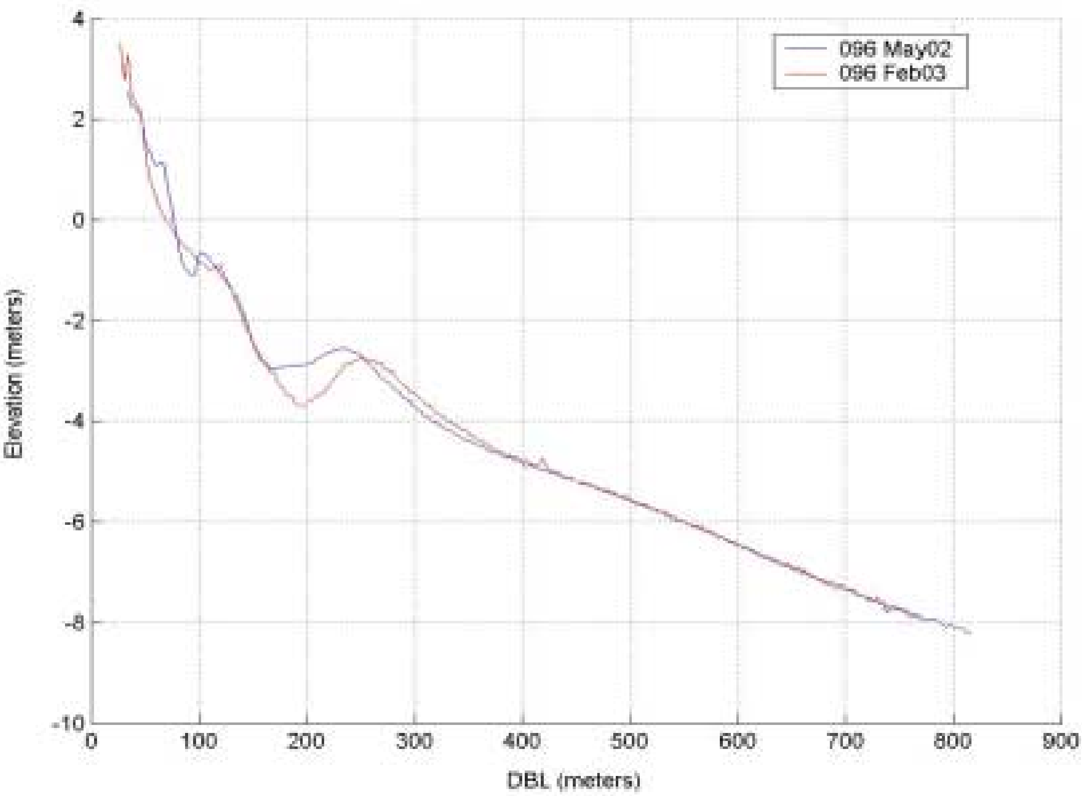
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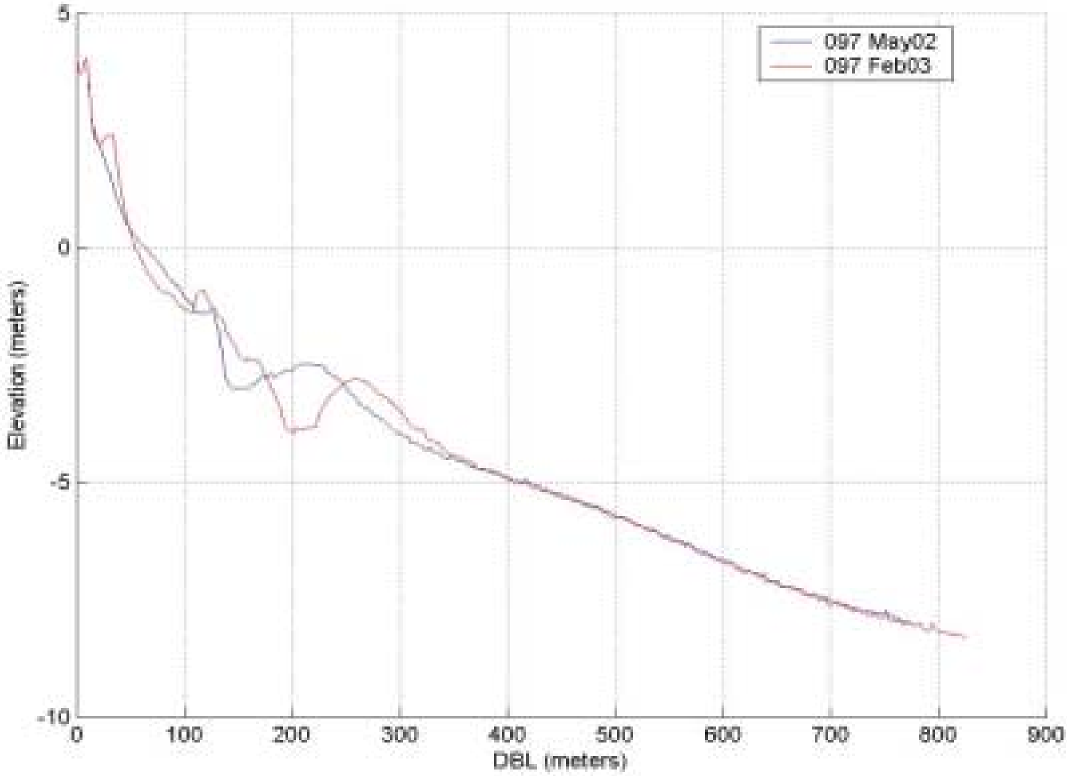
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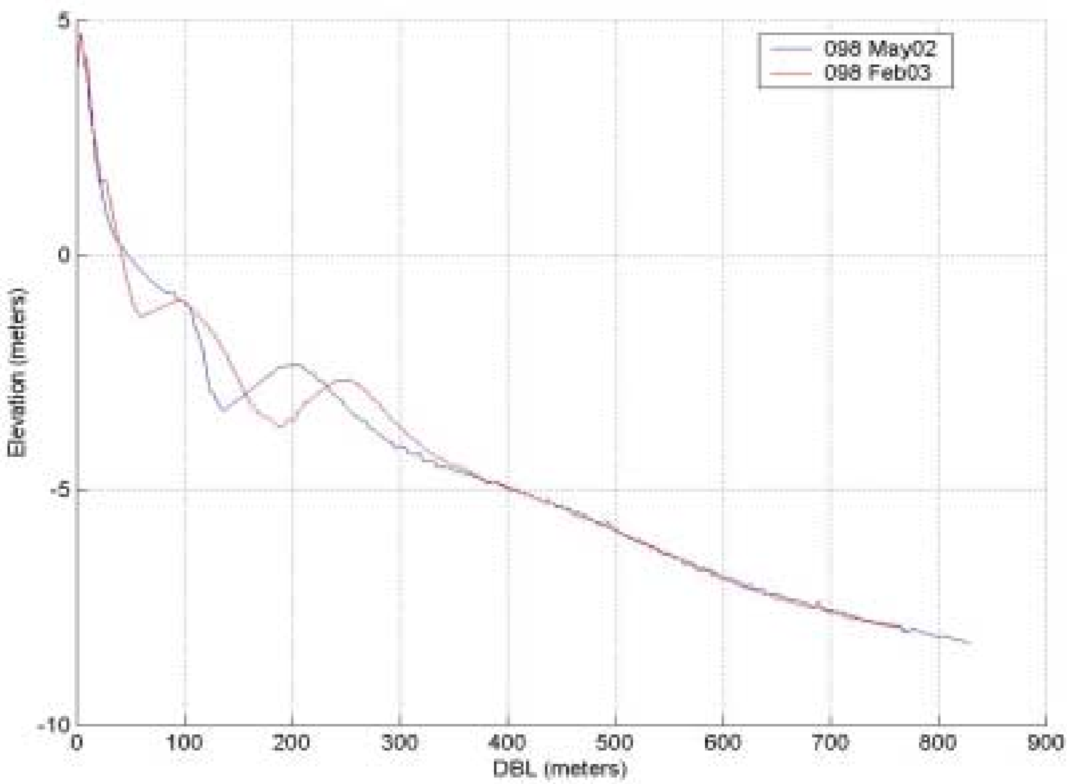
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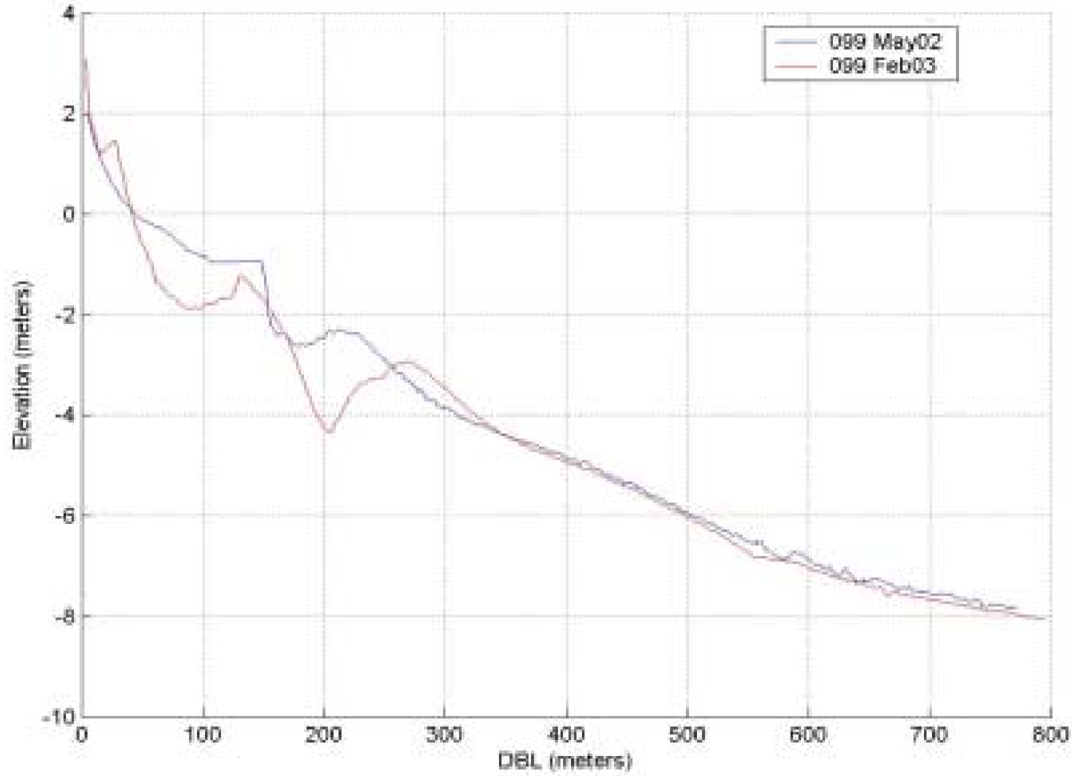

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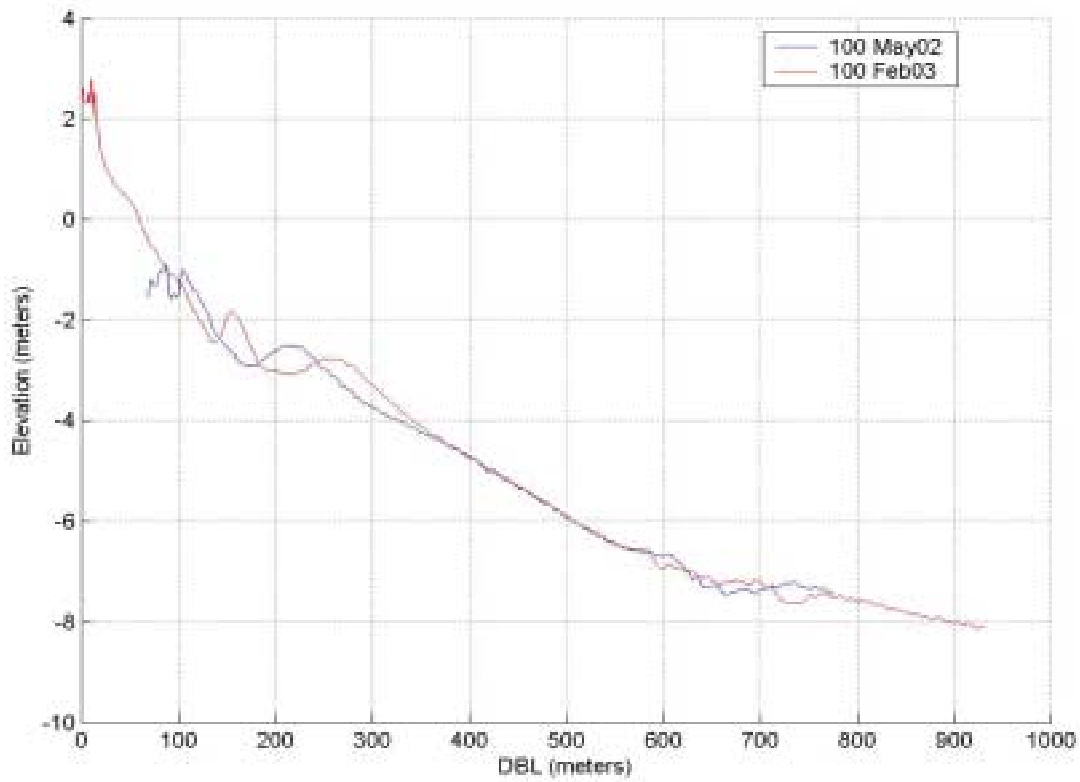
DBL (meters)



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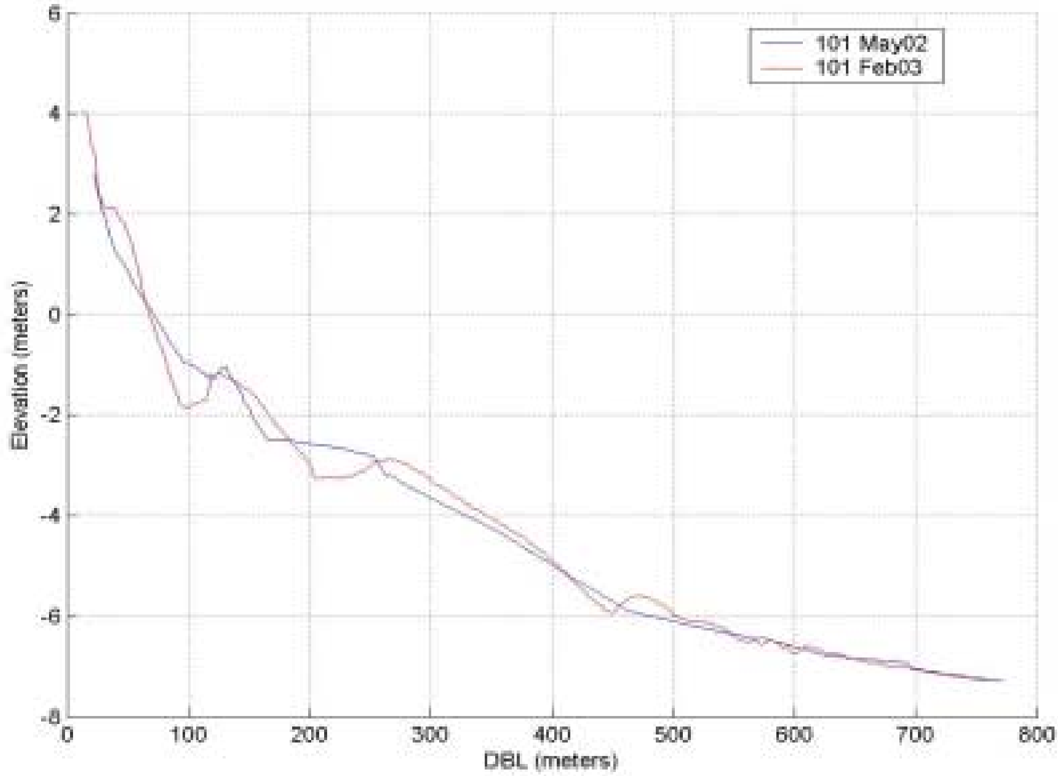
Elevation (meters)
DBL (meters)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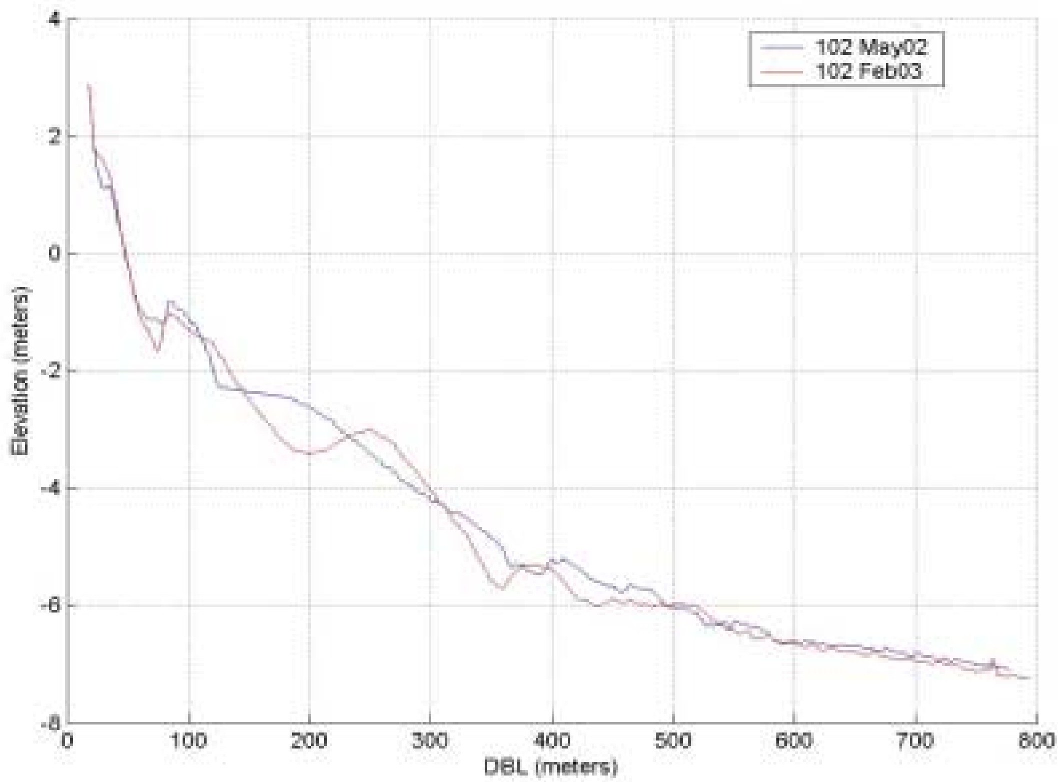
Elevation (meters)
DBL (meters)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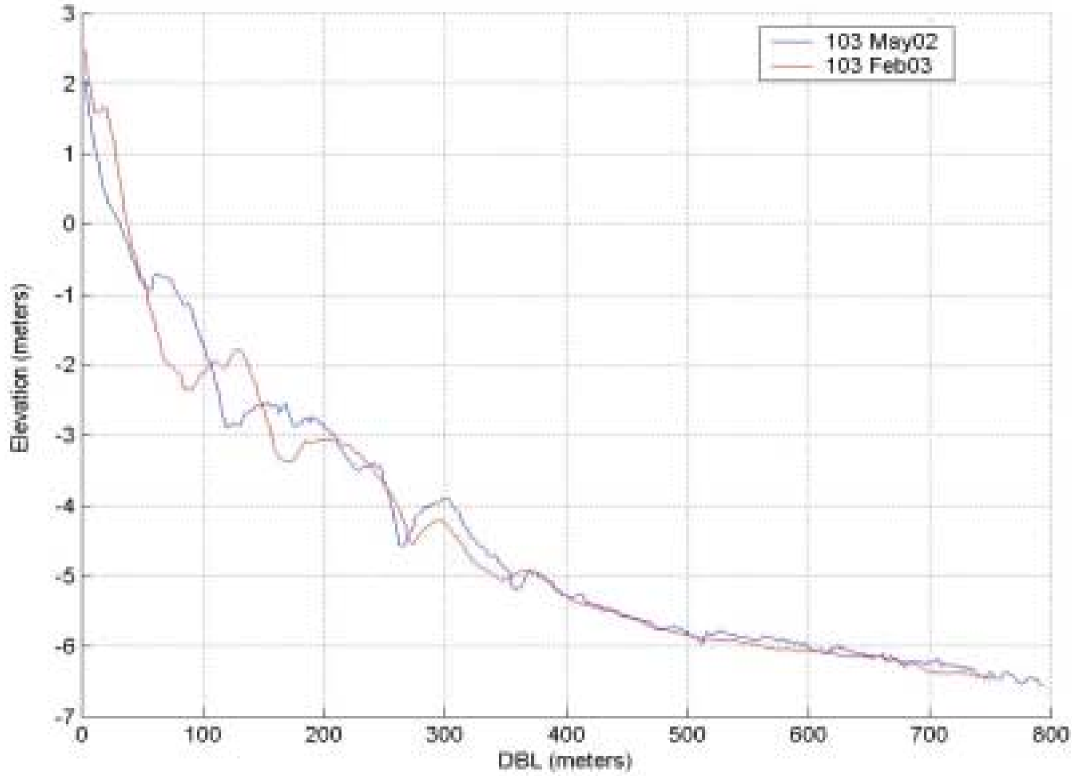
Elevation (meters)
DBL (meters)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DBL (meters)
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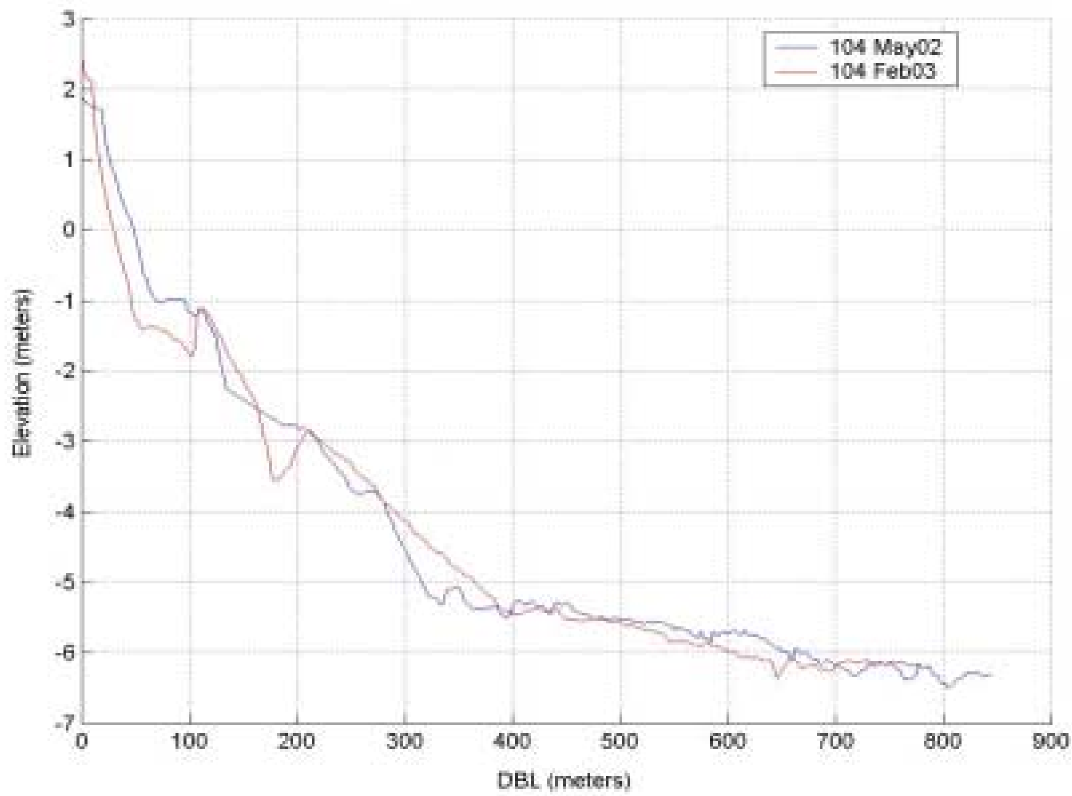
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Elevation (meters)
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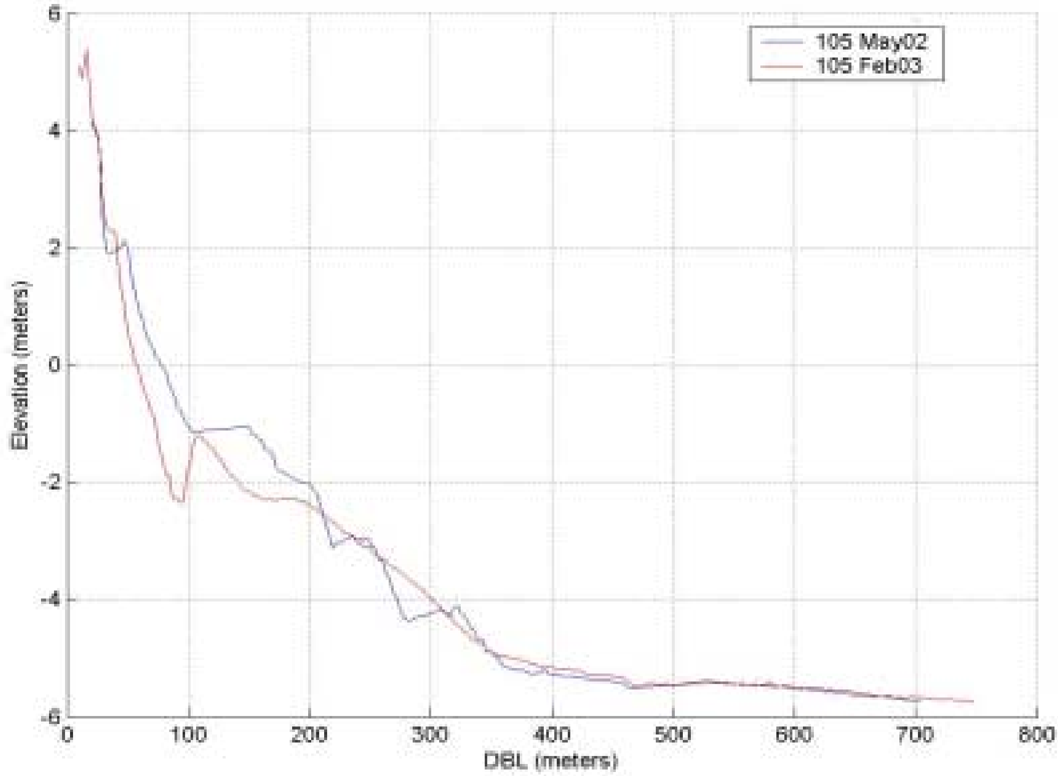

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Elevation (meters)
DBL (meters)
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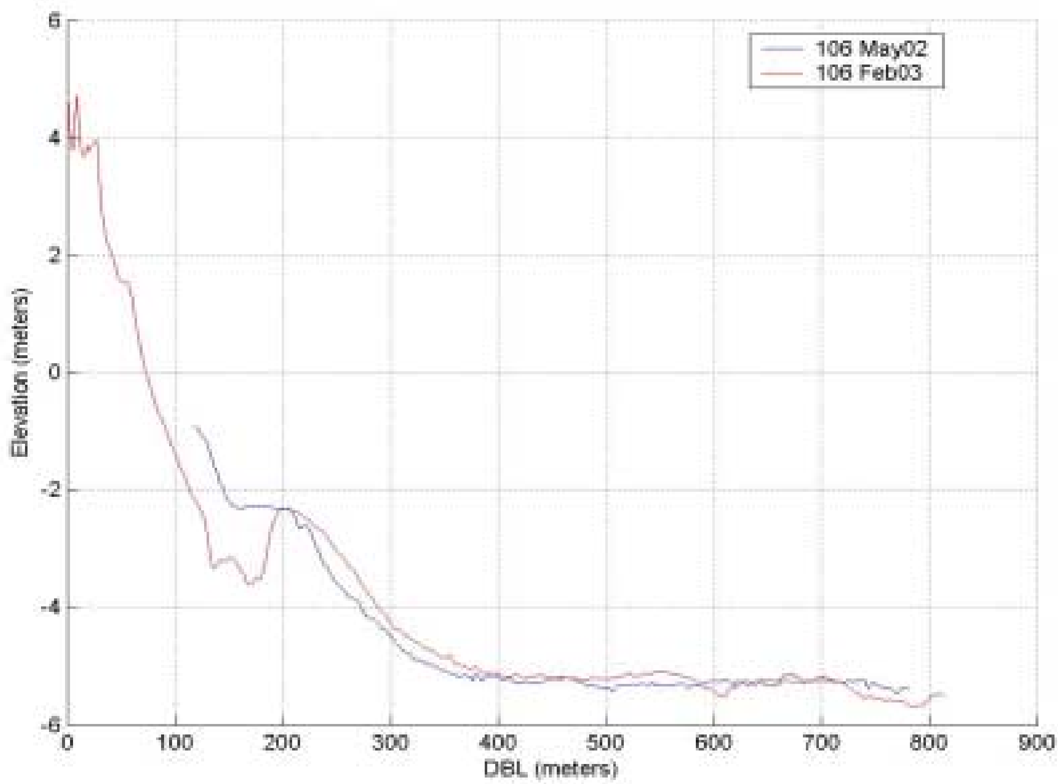

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Elevation (meters)
DBL (meters)
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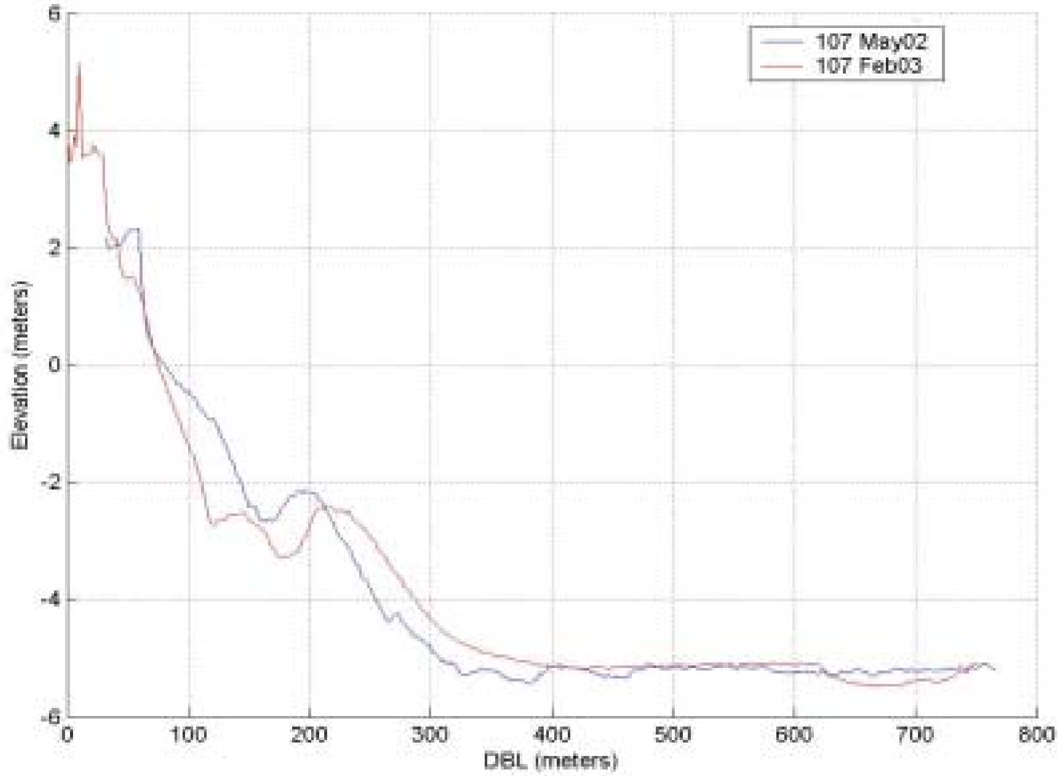
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107 Feb03
Elevation (meters)
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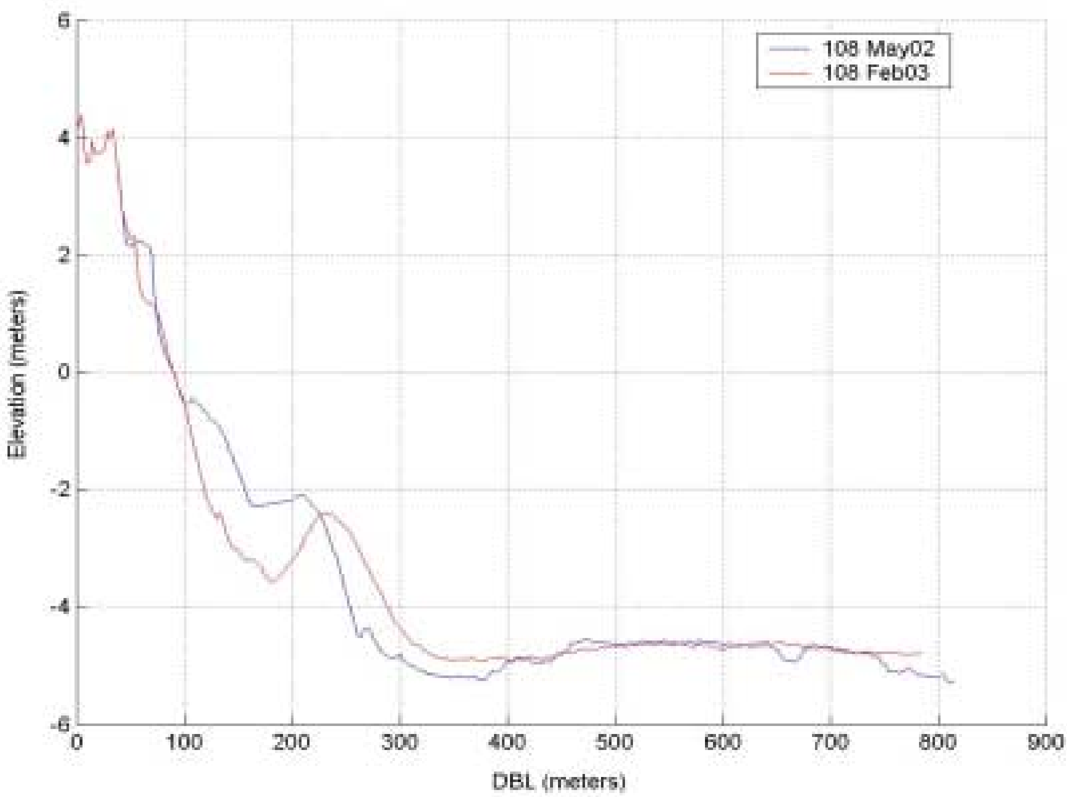
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Elevation (meters)
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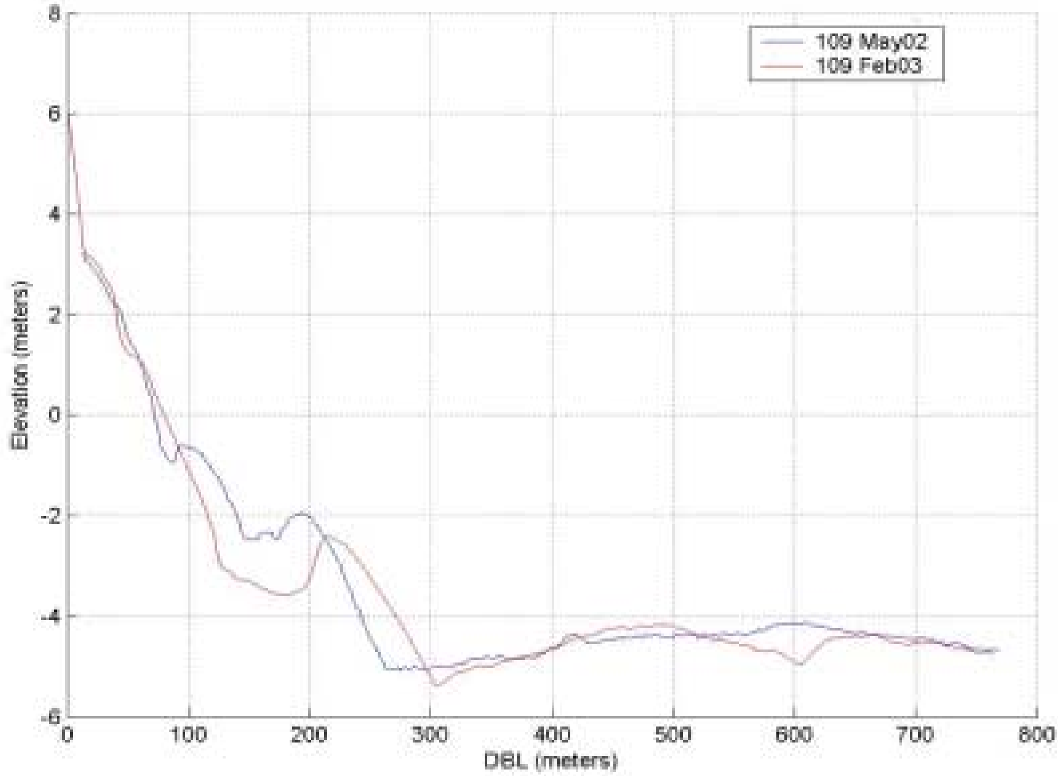
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Elevation (meters)
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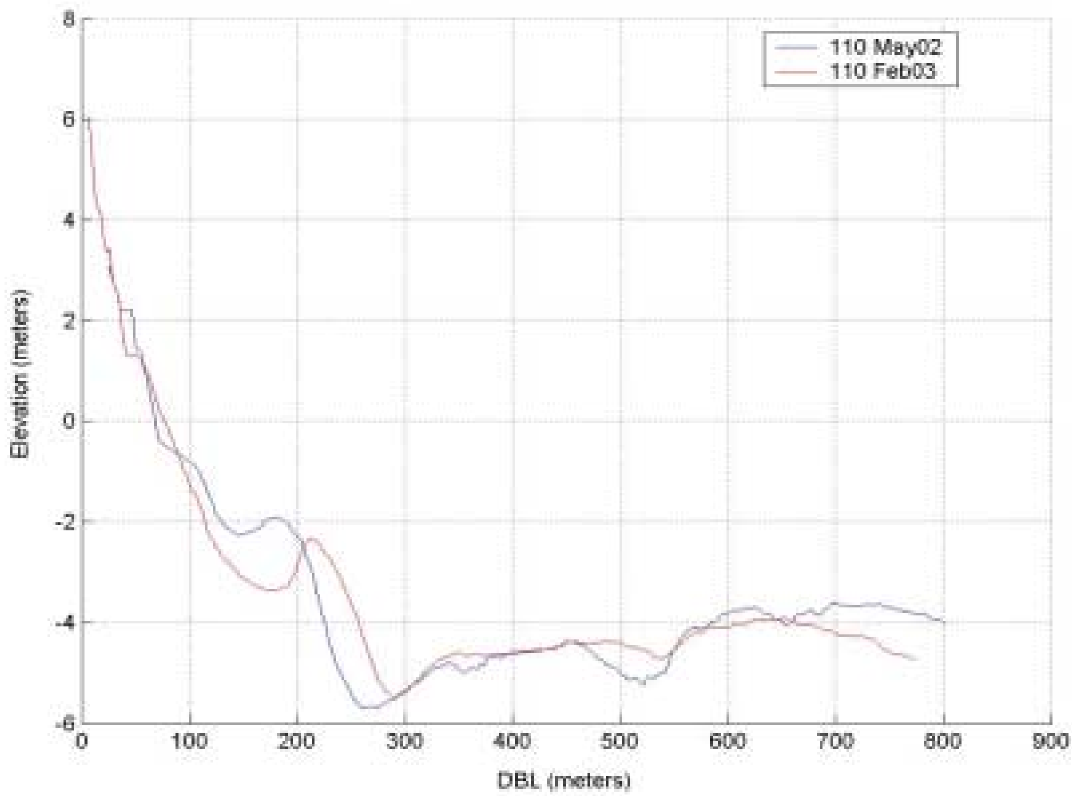
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Elevation (meters)
DBL (meters)
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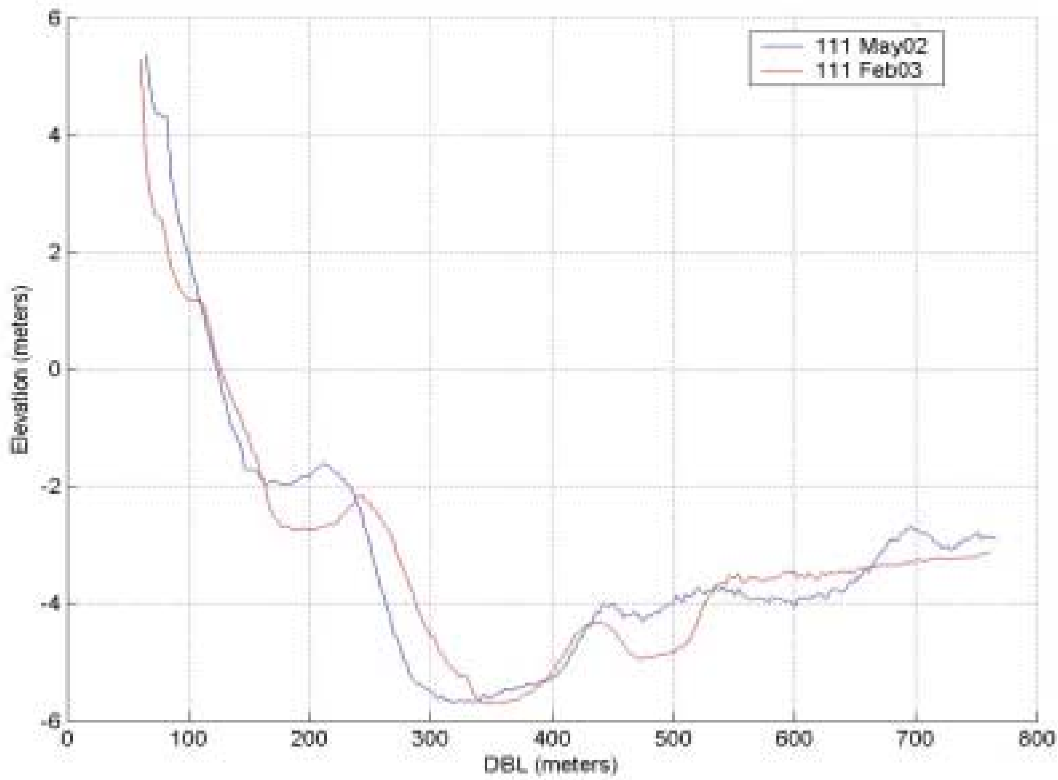
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-2
-4
-6
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600
700
800
DBL (meters)

Appendix C

Grid Volume Tables: Cells G1-G14

May 2002 to January/February 2003

Bogue Banks

		G1	G2	G3	G4	G5	G6	G7
BEACH	Vol. Gain (m^3)	12061.8	27279.8	33928.8	16270.8	26584.6	10180.3	24589.7
	Vol. Loss (m^3)	12870.4	-11622.9	-6326.48	-17489.8	-8239.01	-5065.79	-62372.7
	Net Change (m^3)	-808.669	15656.9	27602.3	-1219.05	18345.6	5114.52	-37783
	Area w/gain (m^2)	51725	124400	106650	59100	58300	51575	70025
	Area w/loss (m^2)	33325	62825	27100	71275	69750	43100	81875
	Total Area (m^2)	85050	187225	133750	130375	128050	94675	151900
OFFSHORE	Vol. Gain (m^3)	85267.8	88570.1	120175	181862	183356	180999	248920
	Vol. Loss (m^3)	-33191.5	-71733.2	-34552.3	-21027.5	-43043.5	-49511.7	-57374.1
	Net Change (m^3)	52076.3	16836.9	85623	160834	140313	131487	191546
	Area w/gain (m^2)	158400	741250	892925	1.02E+06	917375	909850	890100
	Area w/loss (m^2)	115750	573075	323150	235150	281675	285250	274250
	Total Area (m^2)	274150	1.31E+06	1.22E+06	1.25E+06	1.20E+06	1.20E+06	1.16E+06
	Alongshore Dist. (m)	1500	4500	7500	10500	13500	16500	19500

		G8	G9	G10	G11	G12	G13	G14
BEACH	Vol. Gain (m^3)	19228.5	11350.2	31556.8	45842.4	41866.9	40667	371.478
	Vol. Loss (m^3)	-114650	-69496.3	-53298.8	-10949.3	-10463.8	-14674.5	-1664.7
	Net Change (m^3)	-95421.1	-58146.1	-21742.1	34893.2	31403.1	25992.4	-1293.22
	Area w/gain (m^2)	52125	37725	99800	128875	132925	98300	1025
	Area w/loss (m^2)	189075	169700	113075	43275	43100	31925	1625
	Total Area (m^2)	241200	207425	212875	172150	176025	130225	2650
OFFSHORE	Vol. Gain (m^3)	284334	207066	130668	170498	116106	135333	87501.7
	Vol. Loss (m^3)	-50110.9	-59506.2	-129725	-110449	-114585	-200314	-149678
	Net Change (m^3)	234223	147559	943.156	60049.1	1521.29	-64981.2	-62176.8
	Area w/gain (m^2)	880075	849450	653325	751450	705600	637600	444000
	Area w/loss (m^2)	214325	260200	547775	586000	671050	799375	416425
	Total Area (m^2)	1.09E+06	1.11E+06	1.20E+06	1.34E+06	1.38E+06	1.44E+06	860425
	Alongshore Dist. (m)	22500	25500	28500	31500	34500	37500	40500

May 2002 to August 2002

PKS-IB Nourishment Zone

		G7	G8	G9	G10	G11
BEACH	**Vol. Gain (m^3)**	42319.1	44857.9	29826.6	55383.7	54752.3
	Vol. Loss (m^3)	-25189	-36945.5	-41568.7	-12596.9	-33209
	Net Change (m^3)	17130	7912.41	-11742.1	42786.8	21543.2
	Area w/gain (m^2)	82875	100175	91625	165900	130725
	Area w/loss (m^2)	67050	141025	115800	46975	34550
	Total Area (m^2)	149925	241200	207425	212875	165275
OFFSHORE	**Vol. Gain (m^2)**	106291	87350.2	47411.3	76252.2	66122.8
	Vol. Loss (m^2)	-160602	-165634	-147867	-149891	-200373
	Net Change (m^3)	-54310.8	-78284.2	-100456	-73638.9	-134250
	Area w/gain (m^2)	325400	220100	235025	271650	290550
	Area w/loss (m^2)	803275	874300	874625	929450	994150
	Total Area (m^2)	1.13E+06	1.09E+06	1.11E+06	1.20E+06	1.28E+06
	Alongshore Dist. (m)	17700	18000	18300	18600	18900

August 2002 to January 2003

PKS-IB Nourishment Zone

		G7	G8	G9	G10	G11
BEACH	**Vol. Gain (m^3)**	16104.9	13604.1	8902.99	11060.2	41790.5
	Vol. Loss (m^3)	-70418.1	-117090	-55555	-75606.8	-29210
	Net Change (m^3)	-54313.1	-103486	-46652	-64546.6	12580.5
	Area w/gain (m^2)	53450	88625	79975	90275	85050
	Area w/loss (m^2)	100275	154525	130800	125825	82625
	Total Area (m^2)	153725	243150	210775	216100	167675
OFFSHORE	**Vol. Gain (m^3)**	361507	409376	311018	206924	306424
	Vol. Loss (m^3)	-119601	-95136.8	-62574.5	-132014	-113898
	Net Change (m^3)	241906	314240	248444	74909.8	192525
	Area w/gain (m^2)	841400	902625	864125	762425	887425
	Area w/loss (m^2)	290850	199425	246875	445575	397550
	Total Area (m^2)	1.13E+06	1.10E+06	1.11E+06	1.21E+06	1.28E+06
	Alongshore Dist. (m)	17700	18000	18300	18600	18900

January 2003 to April 2003
PKS-IB Nourishment Zone

		G7	G8	G9	G10	G11
BEACH	**Vol. Gain (m^3)**	61116.4	20950.7	10503.9	19037.9	9628.07
	Vol. Loss (m^3)	-20245.4	-33166.1	-26530.1	-25991.8	-58410.9
	Net Change (m^3)	40871.1	-12215.4	-16026.2	-6953.92	-48782.8
	Area w/gain (m^2)	99925	115825	85600	89600	53300
	Area w/loss (m^2)	53800	127325	125175	126500	114550
	Total Area (m^2)	153725	243150	210775	216100	167850
OFFSHORE	**Vol. Gain (m^3)**	398013	57620.8	61968.9	137737	69363.5
	Vol. Loss (m^3)	-114109	-197051	-184641	-112967	-166020
	Net Change (m^3)	283904	-139431	-122672	24770.1	-96656.1
	Area w/gain (m^2)	631775	354425	372750	641575	537750
	Area w/loss (m^2)	498775	747625	738250	566425	745275
	Total Area (m^2)	1.13E+06	1.10E+06	1.11E+06	1.21E+06	1.28E+06
	Alongshore Dist. (m)	17700	18000	18300	18600	18900

May 2002 to April 2003: Year 1 Totals
PKS-IB Nourishment Zone

		G7	G8	G9	G10	G11
BEACH	**Vol. Gain (m^3)**	67159.2	16262.6	8132.59	26241	35403.6
	Vol. Loss (m^3)	-63310.3	-123793	-81999.4	-54005.7	-48711.9
	Net Change (m^3)	3848.87	-107530	-73866.8	-27764.7	-13308.3
	Area w/gain (m^2)	74600	37650	26375	99775	105425
	Area w/loss (m^2)	79125	205500	184400	116325	62425
	Total Area (m^2)	153725	243150	210775	216100	167850
OFFSHORE	**Vol. Gain (m^3)**	561972	233369	181473	177838	157121
	Vol. Loss (m^3)	-91152.8	-137680	-156291	-152394	-195462
	Net Change (m^3)	470819	95688.8	25182.9	25443.1	-38341.3
	Area w/gain (m^2)	812600	577425	604075	658275	588350
	Area w/loss (m^2)	317950	524625	506925	549725	694675
	Total Area (m^2)	1.13E+06	1.10E+06	1.11E+06	1.21E+06	1.28E+06
	Alongshore Dist. (m)	17700	18000	18300	18600	18900

Appendix D

Mean High Water Contour Change

Bogue Banks MHW Contour Change: Lidar 2000 to Jan/Feb 2003

Transect	Northing (spm)	Easting (spm)	Distance Alongshore (m)	Lidar00 - May02 (m)	May02- Jan/Feb03 (m)
1	784027.5083	100908.5801	0	no data	-0.29
2	784120.6067	100844.5643	150	-4.87	-8.27
3	784263.1233	100816.2422	300	-63.33	9.14
4	784383.3155	100770.265	450	-10.05	-5.52
5	784460.0194	100770.2982	600	10.53	-22.12
6	784558.0022	100811.2587	750	33.13	-25.36
7	784597.8239	100832.7955	900	30.8	-19.74
8	784674.7142	100892.0396	1050	21.83	5.13
9	784788.1938	100960.0265	1200	22.32	-5.22
10	784867.9042	101014.6186	1350	14.22	-4.84
11	784954.3426	101055.7546	1500	14.79	-6.53
12	785096.8374	101127.4531	1650	8.98	-1.91
13	785243.9139	101201.904	1800	2.78	1.03
14	785367.2546	101254.5822	1950	10.66	-1.03
15	785503.1121	101303.6093	2100	18.68	-10.91
16	785636.4507	101371.7497	2250	3.74	-2.6
17	785773.6426	101430.5781	2400	0.29	-0.92
18	785930.7513	101492.0295	2550	1.2	2.97
19	786080.986	101545.8353	2700	-5.81	-1.25
20	786229.4614	101605.2704	2850	-8.03	2.34
21	786369.9239	101651.9953	3000	2.12	-3.49
22	786515.6132	101707.0094	3150	8.99	-0.39
23	786663.0316	101757.2976	3300	12.94	-5.05
24	786806.04	101819.6398	3450	-7.23	5.08
25	786959.5386	101862.0561	3600	16.03	-4.39
26	787091.5538	101908.3101	3750	10.55	-3.44
27	787220.4573	101963.4204	3900	-5.11	5.94
28	787354.1119	102005.0083	4050	-2.41	1.56
29	787484.5665	102047.9725	4200	-1.6	0.26
30	787614.7616	102097.155	4350	-7.82	6.29
31	787747.5388	102139.2368	4500	-3.92	4.14
32	787879.1759	102184.4534	4650	-5.34	2.03
33	788010.9412	102229.3178	4800	-8.81	1.44
34	788144.3309	102269.7152	4950	-5.65	0.5
35	788285.9613	102316.1274	5100	-1.57	3.46
36	788423.0652	102358.4958	5250	-3.33	2.1
37	788560.1074	102401.0616	5400	-5.36	1.52
38	788696.1761	102446.7429	5550	-7.32	5
39	788833.2171	102489.3125	5700	-2.8	3.51
40	788973.7868	102532.0639	5850	0.14	1.96
41	789118.4607	102576.1517	6000	-1.86	2.29
42	789263.0997	102620.358	6150	-1.45	3.39
43	789408.1027	102663.3304	6300	-2.89	3.69
44	789554.1185	102702.8707	6450	-1.97	1.17
45	789700.8133	102740.1101	6600	1.15	-3.68

Bogue Banks MHW Contour Change: Lidar 2000 to Jan/Feb 2003
(cont.)

Transect	Northing (spm)	Easting (spm)	Distance Alongshore (m)	Lidar00 - May02 (m)	May02- Jan/Feb03 (m)
46	789846.3432	102780.0995	6750	7.88	-3.61
47	789973.5176	102829.8457	6900	-4.51	4.62
48	790104.913	102865.3737	7050	-0.37	-7.85
49	790235.7477	102902.7904	7200	3.28	-9.39
50	790365.2028	102944.8541	7350	0.03	2.88
51	790496.0637	102982.1825	7500	1.24	4.01
52	790625.9651	103022.7429	7650	-0.97	2.98
53	790753.0584	103064.3023	7800	-5.32	3.5
54	790893.039	103102.6307	7950	-1.73	-0.05
55	791031.6618	103145.3554	8100	-8.14	1.41
56	791171.3913	103184.4968	8250	-7.17	-1.55
57	791310.767	103224.7837	8400	-6.29	-2.33
58	791450.5633	103263.7087	8550	-3.88	-5.19
59	791591.0683	103300.3388	8700	-0.08	-8.98
60	791741.8012	103341.8988	8850	0.77	-7.16
61	791881.2481	103381.3792	9000	0.38	-5.59
62	792021.3206	103418.3202	9150	2.55	-4.72
63	792160.5486	103458.6891	9300	1.72	-1.98
64	792300.583	103495.7846	9450	3.79	-4.82
65	792440.4798	103533.4389	9600	0.85	3.92
66	792580.9116	103568.9216	9750	1.33	-3.78
67	792723.0733	103605.6754	9900	1.97	-1.7
68	792868.621	103642.6015	10050	2.63	-1.29
69	793014.6092	103677.6663	10200	2.52	-3.76
70	793160.6023	103712.7105	10350	0.3	-4.45
71	793306.6087	103747.6983	10500	1.01	-3.6
72	793452.9894	103781.1038	10650	2.1	-5.39
73	793598.8174	103816.8456	10800	-1.94	-3.7
74	793744.3718	103853.7438	10950	-4.01	-2.93
75	793889.8263	103891.064	11100	-2.58	0.42
76	794035.9282	103925.648	11250	1.29	-3.21
77	794181.5965	103962.0648	11400	0.74	-1.92
78	794327.8126	103996.1663	11550	2.26	-2.05
79	794473.222	104033.677	11700	-0.78	-1.38
80	794621.0096	104069.9971	11850	1.77	-2.07
81	794762.7471	104106.5496	12000	1.16	-2.8
82	794904.6645	104142.3102	12150	-0.19	-0.43
83	795047.0905	104175.8332	12300	-2.02	0.55
84	795189.0122	104211.575	12450	-3.79	0.24
85	795331.9164	104242.9935	12600	-3.24	3.71
86	795474.8878	104274.1166	12750	-3.41	-3.59
87	795616.6501	104310.5601	12900	-6.65	-0.46
88	795760.4419	104338.0734	13050	-0.55	-2.43
89	795903.0433	104370.8243	13200	-1.64	-0.7
90	796045.3409	104404.9123	13350	-4.84	0.15
91	796198.4907	104432.8162	13500	1.51	-2.94

Bogue Banks MHW Contour Change: Lidar 2000 to Jan/Feb 2003
(cont.)

Transect	Northing (spm)	Easting (spm)	Distance Alongshore (m)	Lidar00 - May02 (m)	May02- Jan/Feb03 (m)
92	796338.0261	104461.0083	13650	3.07	-5.35
93	796476.6339	104494.1806	13800	-1.64	-1.31
94	796616.9255	104518.3127	13950	-1.06	-5.01
95	796756.1572	104548.1353	14100	-3.04	-5.02
96	796894.9664	104580.2262	14250	-2.43	-2.91
97	797033.988	104611.1763	14400	-1.51	-0.93
98	797173.0406	104641.9601	14550	0.03	0.21
99	797311.6514	104675.1159	14700	-4.14	-0.39
100	797450.5319	104706.8237	14850	-8.06	0.33
101	797589.0794	104740.3194	15000	-9.38	2.05
102	797728.3358	104770.009	15150	-7.8	1.64
103	797867.653	104799.3727	15300	-7.22	0.46
104	797997.5625	104828.0632	15450	-7.3	1.84
105	798144.1867	104858.4249	15600	-7.09	0.53
106	798290.3901	104890.7033	15750	-10.83	-1.33
107	798437.3259	104919.6449	15900	-4.85	-2.65
108	798583.3837	104952.5865	16050	-4.23	-0.13
109	798736.4174	104980.6382	16200	-1.44	-4.93
110	798885.471	105014.4209	16350	-4.91	-2.45
111	799035.3615	105043.9836	16500	-5.69	-4.17
112	799184.6134	105076.766	16650	-7.16	-4.1
113	799335.0808	105103.4205	16800	-0.82	-7.72
114	799484.7865	105133.9151	16950	2.43	-7.35
115	799633.3908	105169.9628	17100	-6.19	-2.02
116	799783.3614	105199.1217	17250	-3.45	-1.38
117	799932.9511	105230.2015	17400	-1.11	-0.53
118	800082.7656	105257.7433	17550	-0.98	-3.2
119	800221.2	105290.0945	17700	-9.69	1.45
120	800361.1999	105314.6173	17850	-5.78	-0.02
121	800500.3746	105343.2666	18000	-5.71	0.14
122	800640.4336	105367.4944	18150	-2.99	-0.72
123	800779.776	105395.3052	18300	-6.7	1.29
124	800919.4325	105421.5456	18450	-0.93	1.5
125	801059.4273	105446.0943	18600	1.65	1.01
126	801203.3301	105476.9929	18750	-5.79	6.94
127	801343.6034	105501.6683	18900	-1.43	3.56
128	801485.1791	105519.1812	19050	8.31	-5.15
129	801623.0706	105556.9567	19200	0.06	2.81
130	801765.6815	105568.7757	19350	19.47	-8.87
131	801908.7551	105578.0496	19500	44.13	-26.84
132	802048.9508	105603.152	19650	52.03	-26.7
133	802191.1392	105629.7565	19800	47.08	-30.28
134	802335.2812	105659.2418	19950	45.85	-28.14
135	802479.3809	105688.972	20100	42.81	-24.23
136	802622.8573	105722.3032	20250	32.87	-18.55
137	802765.9477	105757.8643	20400	31.4	-17.01

Bogue Banks MHW Contour Change: Lidar 2000 to Jan/Feb 2003

(cont.)

Transect	Northing (spm)	Easting (spm)	Distance Alongshore (m)	Lidar00 - May02 (m)	May02- Jan/Feb03 (m)
138	802904.9757	105816.8976	20550	-1.04	17.39
139	803048.2803	105851.2211	20700	-8.5	22.44
140	803196.1509	105859.1637	20850	17.65	2.58
141	803348.2551	105863.5267	21000	38.76	-20.32
142	803487.7409	105881.0051	21150	46.92	-27.18
143	803626.0502	105905.8045	21300	48.03	-27.49
144	803764.5065	105929.6885	21450	51.03	-28.1
145	803902.513	105956.3717	21600	48.82	-26.62
146	804040.869	105980.8799	21750	50.47	-26.8
147	804178.5559	106009.5517	21900	49.69	-21.68
148	804316.9189	106034.0169	22050	47.76	-22.77
149	804455.2353	106058.7718	22200	51.71	-23.47
150	804592.494	106084.4241	22350	51.25	-24.12
151	804728.2631	106109.5645	22500	46.28	-23.99
152	804864.2221	106133.5443	22650	43.75	-24.61
153	804999.7147	106160.3745	22800	39.1	-24.15
154	805135.8562	106183.2392	22950	40.35	-26.75
155	805272.1534	106205.1525	23100	42.7	-27.13
156	805408.0419	106229.5631	23250	41.38	-28.03
157	805543.8972	106254.177	23400	39.65	-26.12
158	805679.5018	106280.3227	23550	37.78	-21.91
159	805814.653	106303.1158	23700	36.88	-23.02
160	805946.8693	106334.6595	23850	27.8	-11.88
161	806081.9022	106349.3033	24000	33.3	-16.82
162	806216.7468	106368.0929	24150	41.9	-19.75
163	806368.3894	106394.5563	24300	40.17	-17.47
164	806521.4586	106412.3813	24450	47.74	-24.12
165	806672.6369	106441.6563	24600	45.45	-19.63
166	806824.6338	106465.9739	24750	47.05	-17.39
167	806976.2295	106492.7212	24900	44.79	-20.95
168	807128.9645	106512.5698	25050	51.37	-18.61
169	807280.6023	106539.062	25200	48.92	-15.77
170	807421.3743	106563.1315	25350	44.26	-12.36
171	807550.7557	106592.446	25500	34.3	-3.68
172	807681.4159	106615.3663	25650	30.68	-2.51
173	807812.2861	106637.2364	25800	25.75	-2.84
174	807943.7509	106656.1336	25950	25.45	-7.42
175	808073.467	106683.7742	26100	13.11	-3.26
176	808233.5067	106701.7302	26250	19.43	-7.68
177	808372.4407	106714.5209	26400	27.55	-12.37
178	808510.1	106739.2083	26550	24.35	-7.61
179	808648.4156	106757.7709	26700	31.4	-8.01
180	808786.7216	106776.4222	26850	34.92	-13.88
181	808923.9281	106805.3356	27000	20.13	-10
182	809062.1645	106824.6377	27150	24	-11.65
183	809199.6992	106850.4881	27300	19.02	-6.02

Bogue Banks MHW Contour Change: Lidar 2000 to Jan/Feb 2003

(cont.)

Transect	Northing (spm)	Easting (spm)	Distance Alongshore (m)	Lidar00 - May02 (m)	May02- Jan/Feb03 (m)
184	809337.9393	106869.7548	27450	23.29	-4.82
185	809484.0059	106882.4114	27600	25.82	-7.97
186	809629.3136	106908.8255	27750	21.14	2.89
187	809775.8575	106921.0241	27900	30.78	-5.11
188	809922.7858	106928.8019	28050	40.3	-26.19
189	810068.1637	106954.4094	28200	34.76	-14.97
190	810213.5444	106979.9844	28350	28.7	-4.65
191	810360.9607	106982.1505	28500	48.8	-21.26
192	810493.8847	106996.7692	28650	51.35	-19.37
193	810630.557	107012.4466	28800	48.85	-12.72
194	810766.6675	107032.7124	28950	45.92	-7.38
195	810903.6003	107046.2625	29100	40.3	-11.76
196	811040.4949	107060.1244	29250	41.5	-10.97
197	811177.8425	107070.2865	29400	48.79	-13.99
198	811315.1395	107080.8628	29550	52.78	-17.6
199	811451.3327	107100.4524	29700	49.87	-10.99
200	811588.4368	107109.6662	29850	54.75	-20.23
201	811739.022	107127.3736	30000	47.92	-16.13
202	811889.0446	107149.6379	30150	41.81	-8.86
203	812040.9556	107156.6069	30300	43.14	-14.72
204	812189.8865	107187.7142	30450	27.68	1.87
205	812340.8243	107202.5653	30600	24.18	-4.25
206	812509.752	107222.8545	30750	21.24	-3.92
207	812643.2629	107235.8674	30900	16.16	-5.25
208	812776.5535	107251.9671	31050	17.78	-0.77
209	812909.8619	107267.8156	31200	12.9	3.72
210	813044.0014	107272.0298	31350	18.85	-4.17
211	813177.5403	107284.6512	31500	14.79	-2.85
212	813310.7603	107301.7386	31650	11.07	1.59
213	813447.8734	107311.9299	31800	2.73	-1.31
214	813590.3968	107323.2774	31950	0.46	-1.46
215	813732.882	107335.2354	32100	-3.71	9.15
216	813875.8258	107339.8563	32250	0.17	-0.07
217	814018.4806	107349.0994	32400	3.68	-0.65
218	814161.2804	107356.024	32550	6.33	2.35
219	814304.5987	107354.653	32700	17.31	-5.29
220	814447.1026	107366.3113	32850	-0.21	-4
221	814590.4708	107364.1421	33000	7.73	-8.38
222	814733.125	107373.3965	33150	1.96	-5.24
223	814907.2556	107382.0696	33300	0.33	-6.06
224	815059.9369	107392.5311	33450	-1.22	-0.29
225	815212.4059	107394.2881	33600	0.74	-4.52
226	815365.0176	107401.8917	33750	4.41	-5.98
227	815517.4574	107402.4535	33900	7.95	-7.88
228	815670.0255	107408.2705	34050	4.65	-6.76
229	815796.9469	107408.6018	34200	6.37	-7.58

Bogue Banks MHW Contour Change: Lidar 2000 to Jan/Feb 2003

(cont.)

Transect	Northing (spm)	Easting (spm)	Distance Alongshore (m)	Lidar00 - May02 (m)	May02- Jan/Feb03 (m)
230	815944.5944	107415.3338	34350	1.82	-4.56
231	816092.5	107415.2236	34500	2.3	-8.11
232	816240.1866	107420.9188	34650	3.96	0.16
233	816388.0202	107422.7171	34800	8.53	0.63
234	816535.9937	107420.8083	34950	8.8	1.27
235	816683.6563	107427.1405	35100	1.76	8.97
236	816831.6816	107423.8585	35250	-5.49	4.85
237	817016.7273	107417.9705	35400	2.02	2.51
238	817164.4171	107418.2277	35550	1.4	6.63
239	817311.9269	107415.513	35700	-5.16	8.29
240	817459.512	107414.0419	35850	-3.2	8.8
241	817607.2358	107414.859	36000	-13.17	18.38
242	817729.6423	107412.4259	36150	-7.08	16.88
243	817863.4003	107402.6479	36300	0.14	9.32
244	817997.1584	107402.6209	36450	-2.37	15.59
245	818130.9164	107392.6168	36600	0.24	7.98
246	818264.6744	107391.7245	36750	-4.72	-3.6
247	818398.4325	107378.8231	36900	3.4	-11.37
248	818576.8715	107366.557	37050	4.62	-11.34
249	818726.2138	107366.9424	37200	-16.48	2.46
250	818873.4198	107349.7034	37350	-8.62	-2.43
251	819021.2807	107337.8668	37500	-12.83	3.31
252	819168.4794	107320.5674	37650	-15.62	6.8
253	819326.5938	107300.3274	37800	-7.04	6.81
254	819476.4438	107286.2343	37950	-5.48	11.26
255	819625.8629	107269.2682	38100	-2.8	7.66
256	819776.6755	107261.5919	38250	-7.97	9.48
257	819925.1519	107238.3411	38400	-0.55	2.61
258	820074.416	107220.3418	38550	-1.58	3.88
259	820199.8051	107204.0764	38700	-0.73	2.29
260	820342.5692	107191.648	38850	-7.81	5.49
261	820484.8417	107173.9759	39000	-4.04	12.87
262	820626.3206	107147.839	39150	6.76	11.61
263	820769.3383	107138.1157	39300	22.88	-14.32
264	820858.6378	107130.528	39450	24.11	-12.58
265	820990.8243	107115.5834	39600	29.4	-20.49
266	821122.4785	107116.3413	39750	19.57	-16.09
267	821254.3094	107111.8837	39900	19.75	-15.48
268	821385.8616	107115.6527	40050	29.79	-2.98
269	821495.0662	107121.296	40200	27.72	3.08
270	821618.5908	107122.3988	40350	19.92	3.26
271	821741.8755	107126.1408	40500	6.96	3.89
272	821864.9515	107132.1782	40650	-7.93	5.85
273	821988.1539	107136.8248	40800	-18.46	5.08

MHW Contour Change: PKS-IB Nourishment Zone

Transect	Northing (spm)	Easting (spm)	Dist. (m)	Lidar00-May02	May02-Aug02	Aug02-Jan/Feb03	Jan/Feb03-April03	May02-April03
120	800361.20	105314.62	17850	-5.78	2.69	-2.71	54.29	54.27
121	800500.37	105343.27	18000	-5.71	6.28	-6.14	54.17	54.31
122	800640.43	105367.49	18150	-2.99	2.56	-3.28	51.81	51.09
123	800779.78	105395.31	18300	-6.7	2.18	-0.89	43.64	44.93
124	800919.43	105421.55	18450	-0.93	10.99	-9.49	35.86	37.36
125	801059.43	105446.09	18600	1.65	14.91	-13.9	34.37	35.38
126	801203.33	105476.99	18750	-5.79	20.59	-13.65	19.9	26.84
127	801343.60	105501.67	18900	-1.43	19.12	-15.56	12.13	15.69
128	801485.18	105519.18	19050	8.31	11.67	-16.82	3.52	-1.63
129	801623.07	105556.96	19200	0.06	23.15	-20.34	0.91	3.72
130	801765.68	105568.78	19350	19.47	10.36	-19.23	-2.97	-11.84
131	801908.76	105578.05	19500	44.13	-6.81	-20.03	-2.04	-28.88
132	802048.95	105603.15	19650	52.03	-10.2	-16.5	-3.11	-29.81
133	802191.14	105629.76	19800	47.08	-9.84	-20.44	-1.01	-31.29
134	802335.28	105659.24	19950	45.85	-12.52	-15.62	-2.52	-30.66
135	802479.38	105688.97	20100	42.81	-11.7	-12.53	-6.38	-30.61
136	802622.86	105722.30	20250	32.87	-8.3	-10.25	-5.13	-23.68
137	802765.95	105757.86	20400	31.4	-2.92	-14.09	-1.3	-18.31
138	802904.98	105816.90	20550	-1.04	30.69	-13.3	-2.61	14.78
139	803048.28	105851.22	20700	-8.5	35.7	-13.26	0.78	23.22
140	803196.15	105859.16	20850	17.65	17.18	-14.6	-3.64	-1.06
141	803348.26	105863.53	21000	38.76	-2.05	-18.27	0.44	-19.88
142	803487.74	105881.01	21150	46.92	-4.82	-22.36	-0.5	-27.68
143	803626.05	105905.80	21300	48.03	-5.98	-21.51	2.8	-24.69
144	803764.51	105929.69	21450	51.03	-5.05	-23.05	0.24	-27.86
145	803902.51	105956.37	21600	48.82	-7.02	-19.6	1.53	-25.09
146	804040.87	105980.88	21750	50.47	-5.39	-21.41	4.33	-22.47
147	804178.56	106009.55	21900	49.69	-2.74	-18.94	2.26	-19.42
148	804316.92	106034.02	22050	47.76	-3.96	-18.81	3.94	-18.83
149	804455.24	106058.77	22200	51.71	-3.26	-20.21	-0.44	-23.91
150	804592.49	106084.42	22350	51.25	-8.58	-15.54	-2.83	-26.95
151	804728.26	106109.56	22500	46.28	-8.3	-15.69	-2.15	-26.14
152	804864.22	106133.54	22650	43.75	-10.77	-13.84	-3.34	-27.95

MHW Contour Change: PKS-IB Nourishment Zone
(cont.)

Transect	Northing (spm)	Easting (spm)	Dist. (m)	Lidar00-May02	May02-Aug02	Aug02-Jan/Feb03	Jan/Feb03-April03	May02-April03
153	804999.71	106160.37	22800	39.1	-7.41	-16.74	-1.92	-26.07
154	805135.86	106183.24	22950	40.35	-8.96	-17.79	0.16	-26.59
155	805272.15	106205.15	23100	42.7	-11.75	-15.38	-2.15	-29.28
156	805408.04	106229.56	23250	41.38	-10.23	-17.8	-0.75	-28.78
157	805543.90	106254.18	23400	39.65	-7.95	-18.17	-0.54	-26.66
158	805679.50	106280.32	23550	37.78	-6.12	-15.79	-0.73	-22.64
159	805814.65	106303.12	23700	36.88	-6.56	-16.46	-0.97	-23.99
160	805946.87	106334.66	23850	27.8	1.86	-13.74	-2.65	-14.53
161	806081.90	106349.30	24000	33.3	-6.93	-9.89	-1.35	-18.17
162	806216.75	106368.09	24150	41.9	-12.29	-7.46	-0.66	-20.41
163	806368.39	106394.56	24300	40.17	-11.23	-6.24	0.26	-17.21
164	806521.46	106412.38	24450	47.74	-16.92	-7.2	-0.16	-24.28
165	806672.64	106441.66	24600	45.45	-15.53	-4.1	2.01	-17.62
166	806824.63	106465.97	24750	47.05	-14.81	-2.58	-1.49	-18.88
167	806976.23	106492.72	24900	44.79	-14.63	-6.32	7.1	-13.85
168	807128.96	106512.57	25050	51.37	-17.92	-0.69	1.54	-17.07
169	807280.60	106539.06	25200	48.92	-17.39	1.62	1.63	-14.14
170	807421.37	106563.13	25350	44.26	-12.35	-0.01	2.43	-9.93
171	807550.76	106592.45	25500	34.3	-4.7	1.02	-1.77	-5.45
172	807681.42	106615.37	25650	30.68	-0.75	-1.76	-1.95	-4.46
173	807812.29	106637.24	25800	25.75	1.04	-3.88	-1.04	-3.88
174	807943.75	106656.13	25950	25.45	1	-8.42	-4.27	-11.69
175	808073.47	106683.77	26100	13.11	4.82	-8.08	-2.06	-5.32
176	808233.51	106701.73	26250	19.43	5.36	-13.04	-6.33	-14.01
177	808372.44	106714.52	26400	27.55	-7.34	-5.03	-3.88	-16.25
178	808510.10	106739.21	26550	24.35	0.05	-7.66	0.14	-7.47
179	808648.42	106757.77	26700	31.4	-4.91	-3.1	-1.68	-9.69
180	808786.72	106776.42	26850	34.92	-6.04	-7.84	-1.67	-15.55
181	808923.93	106805.34	27000	20.13	0.58	-10.58	6.89	-3.11
182	809062.16	106824.64	27150	24	-0.64	-11.01	-0.1	-11.75
183	809199.70	106850.49	27300	19.02	2.09	-8.11	4	-2.02
184	809337.94	106869.75	27450	23.29	4.75	-9.57	3.25	-1.57
185	809484.01	106882.41	27600	25.82	-8.45	0.48	-1.64	-9.61

MHW Contour Change: PKS-IB Nourishment Zone
(cont.)

Transect	Northing (spm)	Easting (spm)	Dist. (m)	Lidar00-May02	May02-Aug02	Aug02-Jan/Feb03	Jan/Feb03-April03	May02-April03
186	809629.31	106908.83	27750	21.14	-0.51	3.4	-2.49	0.4
187	809775.86	106921.02	27900	30.78	-6.82	1.71	-3.47	-8.58
188	809922.79	106928.80	28050	40.3	-14.57	-11.62	2.3	-23.89
189	810068.16	106954.41	28200	34.76	-7.13	-7.84	3.98	-10.99
190	810213.54	106979.98	28350	28.7	3.36	-8.01	3.84	-0.81
191	810360.96	106982.15	28500	48.8	-9.12	-12.14	7.06	-14.2
192	810493.88	106996.77	28650	51.35	-9.37	-10	4.39	-14.98
193	810630.56	107012.45	28800	48.85	-4.26	-8.46	-2.96	-15.68
194	810766.67	107032.71	28950	45.92	5.73	-13.11	-5.57	-12.95
195	810903.60	107046.26	29100	40.3	4.26	-16.02	5.32	-6.44
196	811040.49	107060.12	29250	41.5	1.86	-12.83	3.61	-7.36
197	811177.84	107070.29	29400	48.79	-2.4	-11.59	3.09	-10.9
198	811315.14	107080.86	29550	52.78	-3.52	-14.08	3.02	-14.58
199	811451.33	107100.45	29700	49.87	-0.83	-10.16	-2.89	-13.88
200	811588.44	107109.67	29850	54.75	-0.52	-19.71	-0.64	-20.87
201	811739.02	107127.37	30000	47.92	1.18	-17.31	0.58	-15.55
202	811889.04	107149.64	30150	41.81	2.19	-11.05	0.85	-8.01
203	812040.96	107156.61	30300	43.14	-9.27	-5.45	-1.35	-16.07
204	812189.89	107187.71	30450	27.68	6.02	-4.15	-2.58	-0.71
205	812340.82	107202.57	30600	24.18	4.96	-9.21	0.69	-3.56
206	812509.75	107222.85	30750	21.24	6.37	-10.29	6.36	2.44
207	812643.26	107235.87	30900	16.16	4.29	-9.54	3.28	-1.97
208	812776.55	107251.97	31050	17.78	5.92	-6.69	5.49	4.72
209	812909.86	107267.82	31200	12.9	10.06	-6.34	1.23	4.95
210	813044.00	107272.03	31350	18.85	0.14	-4.31	-1	-5.17
211	813177.54	107284.65	31500	14.79	3.68	-6.53	-1.38	-4.23
212	813310.76	107301.74	31650	11.07	3.79	-2.2	0.52	2.11
213	813447.87	107311.93	31800	2.73	1.41	-2.72	1.75	0.44
214	813590.40	107323.28	31950	0.46	-0.28	-1.18	2.21	0.75
215	813732.88	107335.24	32100	-3.71	4.06	5.09	-8.78	0.37
216	813875.83	107339.86	32250	0.17	0.53	-0.6	-3.08	-3.15
217	814018.48	107349.10	32400	3.68	-0.66	0.01	1.83	1.18
218	814161.28	107356.02	32550	6.33	2.06	0.29	-1.87	0.48